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# RECYCLED HOT MIXES

# AN EVALUATION OF FIVE YEARS TREND ON MATERIAL PROPERTIES

MATERIALS INFORMATION
ENGINEERING MATERIALS OFFICE

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## INTRODUCTION

Since 1980, when the Ministry embarked on hot mix recycling as a pavement rehabilitation alternative, 3.5 million tonnes of recycled hot mix pavement have been placed in the Ontario provincial highways. This tonnage translates into an average of 700,000 tonnes per year or 45% of the Ministry's annual placement of hot mixes.

This commitment is based on the projected saving in construction cost and conservation of expensive and non-renewable natural resources i.e. asphalt cement and aggregate. However, it is also perceived that there are performance problems with RHM and that improvement is needed in the area of material mix design as well as performance of recycled hot mixes. This points to the need for continual monitoring of construction and field performance, and data logging of all recycling contracts to identify problem areas. Some of these problems can be foreseen, such as the difficulty in getting desirable asphalt cement penetration, others are on individual contract basis as in the case of obtaining suitable blending sand to improve mix properties.

It is the purpose, therefore, of this report to provide a data base on which the different problem areas can be identified, on a local as well on a provincial level. It also provides information for continual evaluation of the trend in material properties in each of the regions.

Also included in this report is a formula that is developed by the writer for the designer to predict the penetration of the recovered asphalt cement in the final RHM. The formula is based on the correlation between the field data collected and detailed laboratory studies. It can also be used for selecting the appropriate recycling ratio and the proper grade of new asphalt cement to give a desirable final penetration in the RHM.

DATA COLLECTION

There were 108 contracts involving the use of recycled mixes during the five years period from 1980 to 1984. It is noted that, however, Southwestern and Central Region have not had any recycling contract until 1982. The total tonnages up to the end of 1984 for the five regions are as follows:

| | |
|---|---|
| Southwestern | 407,250 |
| Central | 852,000 |
| Eastern | 70,500 |
| Northern | 1,043,500 |
| Northwestern | 1,073,000 |
| Total | 3,446,250 |

The data collected was compiled from that available in the Bituminous Section office files up to the end of September 1985, and was assembled under three different categories as discussed in the next section. The data presented in an earlier report M1 68 " Hot Mix Recycling Data Bank on Material Properties" are not included in the data base of this report but is included in the analysis. The package of data was then sent to each region for comment and filling in of additional data. However, there is a very small amount of data that the regions were unable to provide Also, some plant checks results were not finalized, at least up to the cut-off point (at the end of September 1985) that was planned for completion of data collection.

Contracts that made use of the up to 25% option of including RAP in either the HL4 or HL8 binder course were omitted from this study. This is because the exact proportions of RAP in the actual mix were not known.

A small number of asphalt cement penetration data was collected from contracts where complete analysis on the RAP A.C. virgin A.C. and frequent samples of RHM has been performed. The 1981 results were obtained from three of the regions involved in recycling hot mixes. However, the 1982 results were mainly from the Eastern Region, the 1983 results from Southwestern Region and Northwestern Region, and the 1984 results from Northwestern Region.

## RECORDING OF DATA

For ease of reference, the data collected from different contracts is recorded under three different sections for each of the regions.

A) General information (Appendix 1) - highway number, location, A.A.D.T., quantity, recycling ratio.

B) Mix design information (Appendix 2) - lift, RAP proportion, virgin aggregate properties, % A.C., sand content, % voids, flow, stability, VMA.

C) Plant check results (Appendix 3) - % A.C., sand content, % voids, flow, stability, % VMA, BRD, MRD.

The information is arranged in such a way as to follow the sequence of operation, e.g. pre-engineering contract data, mix design and construction. In the plant check data base (Appendix 3) the values of different properties were presented in their averages and the standard deviations.

## ANALYSIS OF RESULTS

The material properties evaluated in this report are as follows:

- Sand Content
- Void Content
- Marshall Flow
- Marshall Stability
- VMA
- A.C. Penetration

Analysis was conducted on a regional basis for each of the five material properties listed above. Under each contract, all mix design, plant check and specification or desirable values were plotted in Figs 1 - 25 and identified as to the surface and binder courses. The grand average for each of the years was also plotted to show the general trend.

Tables were also compiled for each of the material properties. Each table summarizes a material property for surface and binder courses under both mix

design values and plant check results. The property values were then classified according to the year of paving and the region responsible for the contract. The results were analyzed in respect to their averages, range, % in-specification and the number of mixes monitored. The % in-specification rate is the proportion of values within what is specified in the standard specification Form 1150,, or is the desirable range within which the value should fall.

To show the progression over the five year period of hot mix recycling on a provincial basis, a bar chart showing the percentage of mixes meeting the specifications for both the mix design and plant check values is presented in Figure 26.

In order to assess the level of A.C. penetration obtainable from R.H.M., asphalt cement results were analyzed in respect to the contribution of "one or two-grade softer" virgin A.C. to the percentage of desirable, penetration. The desirable penetration is determined on the basis of about 60% retained on the penetration of the grade of A.C. that would be used in a virgin mix on the same location (Table 6). The retained penetration allows for the amount of A.C. hardening to be expected during mixing of a hot mix.

## DISCUSSION OF RESULTS

A short discussion is made under each of the material properties listed above for each of the regions, to point out extreme values and trends over the five year period, specifically addressing the average, range, % in-specification and the number of mixes. Finally, a general trend on the recycling mix properties over the five years for all the five regions is discussed.

<u>% Sand (Fig 1-5, Table 1)</u>

Southwestern Region:

- The analysis of this region is limited to the three year period 1982-84 as no recycled hot mix was laid in 1980 and 81.
- Mixes in this region had the highest average sand content in the province (i.e. x = 62%) with most values ranging between 60 and 65 percent. This leads to the lowest % In-Spec. rate in the province. This is due mainly to the extensive use of milled RAP in the RHM.
- However, the 1984 % In-Spec. rate has shown substantial improvement i.e. both surface and binder courses have 45 to 50% increase from zero percent in 1983. (Table 1).
- Also, as seen from the annual mix design and plant check averages in Figure 1, the tendency seems to confirm that the increasing use of separate stone and blending sand in the region to ensure compliance of mix properties to specification had improved the sand content situation i.e. decreasing % sand value in a mix.
- The % In-Spec. rate is higher for the surface than the binder course in both the mix design and plant check values.

Central Region:

- Along with Southwestern Region, Central Region started in recycling only in 1982.
- The design values for sand content were predominantly specified at 55% and a high % In-Spec rate was resulted over the three years (i.e. 90%).
- Plant check values distributed around the design target and lower % In-Spec. rate was obtained as compared with mix design.
- The general trend as seen from the annual averages is that the % sand was maintained around the 56% area.

Eastern Region:

- This region had only a few recycling projects over the four year period.
- The annual averages showed both mix design and plant check values were within the desirable range of 55 to 60%, with plant checks generally finer than the mix designs and a higher % In-Spec. rate.

Northern Region:

- Most mix design values were within the desired range resulting in a high % In-Spec rate (about 75% for 1984).
- Field results were generally higher than design, distributing around the upper limit of the desired range (i.e. average at 60%) and yielding lower % In-Spec rate (52% for 1984).
- There appears to be a slight trend over the years towards lowering the sand content to within the desired range.

Northwestern Region:

- This region had the most recycling contracts so far (i.e. 28 up to 1984).
- The mix designs were predominantly at a sand content of 60% i.e. upper limit of the desirable range.
- Field results were often slightly above the mix design yielding more sandy mixes. (These types of mixes may be suitable for the Northern province environment due to the lighter traffic and generally requiring more flexible pavement construction provided there is sufficient A.C. in the mix).
- A trend towards a lower percentage of sand in the mix is evident as more mixes are designed at 55% sand.

% Voids (Fig 6-10, Table 2)

Southwestern Region:

- Majority of the mix design values were at a void content of about 3% in 1982 and 1983 with the average moving slightly higher in 1984.
- Field results were generally lower than design values resulting in a low % In-Spec rate (i.e. 13%).
- The difference between mix designs and plant checks may indicate difficulty in obtaining representative samples for mix design e.g. using cores comparing to the milled materials.

Central Region:

- Over the three year period (1982 - 84), the average of the % voids was the lowest in the province. This applies to both mix designs and plant checks (2.1 and 1.8 respectively).
- Similar to the Southwestern Region, Central Region extensively used milled RAP materials in the recycling contracts. This leads to the difficulty in obtaining the required voids in the mix.
- Consequently, the % In-Spec rate was the lowest in the province for mix design and plant check values (i.e. 7% and 6% respectively).

Eastern Region:

- Mix design and field results are all within the range between 2 and 4 percent.
- The values appear to be moving into the specified range of 3 to 5% over the four years.

Northern Region:

- Over the five year period, majority (over three quarters) of the values is within the range between 2.5 to 3.5%.
- Field results were usually within half a percent of the mix design values.
- The 1984 annual averages of both plant checks and mix design indicate a downward trend from previous years. The % In-Spec rate is consequently lower.

Northwestern Region:

- Values are distributed around the 3% voids with most values ranging between 2 and 4 percent.
- The general reduction in the sand content as seen in Fig. 5 appears to correspond to the slight upswing trend in % voids as shown in the 1983-84 annual averages in Fig. 10.
- Field results correlate closely to design values.
- The % In-Spec rate is higher for the mix design values than for the plant checks, same as in the other region.

Flow (Figs 11-16, Table 3)

Southwestern Region:

- With the exception of a few contracts, flow values range between 10 and 13 for both plant checks and mix design.
- A trend over the three years towards lower flows can be observed.
- It is noted that contract 82-30 has very high plant check flow values i.e. 18 to 20. (The corresponding stability values are also high).

Central Region:

- A large range of values were obtained for both mix designs and plant checks (9.8 - 27.4, 11 - 23.6 respectively).

- The region also had the greatest deviation of plant check results from mix design values. This difference appears to warrant some investigation. It could be due to differences between laboratory and field mixing, handling, testing and use of asphalt cement and RAP.
- All results (except one) were above the specification minimum of 10, with some values much higher than the normal range of between 10 - 16.

Eastern Region:

- Most mixes in 1982 and 84 had lower flow values than 10.
- Similar to Central Region, in 1984 the mix designs had a lower flow values than plant checks.

Northern Region:

- Consistent mix design values and plant check results are evident as over 80% of the values are within the small range of 11 to 14.
- Except two mixes falling short of the specification minimum, this region has a high % In-spec rate (i.e. 97%) over the five year period.

Northwestern Region:

- The values ranged from 7 to 16 with most of the flow values in the lower half of this range.
- 1983 and 84 results show a lowering trend towards a flow level of 9.

Stability (Figs 16-20, Table 4)

Southwestern Region:

- The stability values ranged from 8000 to 19,000 N, which were typical of mixes in the other regions
- All values achieved the specification minimum i.e. greater than 8,000 N.
- Plant check results indicate field stability is higher than mix designs.

Central Region:

- Stability values were the highest in the province averaging 16,000 N and 14,900 N for mix design and plant checks results respectively.
- The high stability together with low flows value as mentioned previously tends to suggest that some of the recycled mixes were very stiff and difficult to compact. High stability can be a plus for Central region in view of the mostly heavy traffic roads in the region, and could be as a result of using RAP from reclaimed HL 1 (i.e. 85/100 versus 150/200) is normally designed for mixes in this Region.
- There was a large spread of values ranging from 9,800N to 23,500N.
- Unlike the other regions, 1982 and 1983 field results were often below mix design values. (This further reinforces the need for investigating the difference).

Eastern Region:

- Most mixes had values between the 8,000 to 14,000N range with a few mixes just exceeding the specification minimum by a small margin.
- Annual averages indicate that the plant checks were close to the mix design values.

Northern Region:

- Over the five years, most of the mixes used had stability consistently between a range of 10,000N to 16,000N.
- Similar to the other regions field mixes produced stability values above those in the design.

Northwestern Region:

- Similar higher plant check to mix design stability values were obtained.
- Most values ranged from 8,000 to 18,000N which was typical of mixes in other regions.

VMA (Figs. 21 - 25, Table 5)

Southwestern Region:

- Field results were often lower than mix design values.
- There were large spread of results in the years 1983 and 84 than with the 1982.
- The annual averages indicated that there was an increasing difference between field results and mix design values over the three year period.
- Plant check results showed low % In-Spec rate (15% over the three years, Table 5).

Central Region:

- There were an average of six binder course mixes put down each year between 1982 and 1984. The annual averages indicated that, although there was an improvement in the VMA value in mix designs, the plant checks had decreased since 1982.
- For surface course mixes, the only significant number of mixes (five) put down was in 1983.
- The field values showed lower average as well as % In-Spec rate than mix design.
- The percent VMA ranged the largest among the regions for both mix designs and plant checks (i.e. 12.1-16.3, 9.5-18.2 respectively)

Eastern Region:

- As seen from the 1982 results (the only year with a fair number of mixes placed, the plant checks values were closer to the specification minimum than mix design values.
- The % In-Spec rate for the plant checks was the highest among the regions (65%).

Northern Region:

- Mix designs were much lower than the plant checks (about 15% versus 13.7% respectively) between 1980 and 1982.
- The 1984 results showed a narrower gap between plant checks and mix designs, but both were at a lower level than those for previous years.

Northwestern Region:

- Mix design and plant check values were quite close to one another.
- The annual averages indicate that there is a trend for improvement towards meeting the specification minimums as the gap between the designs and specified values narrows.

GENERAL TREND OF MIX PROPERTIES

In order to examine the general trend of the five mix properties over the past five years at the provincial level, the % In-Spec rate for each property was averaged and plotted in Fig. 26. They are discussed below:

Sand Content:

- For mix design, an average 70% In-Spec rate is obtained. Perhaps it can be viewed that there is a 70% chance of getting a mix meeting a desirable level of sand content. The 70% level seems to be very constant for the five years.
- The plant check results indicate a steady improvement of sand content in a mix from about 20% In-Spec rate to 40% between 1980 and 1984.
- This improvement has to do with the greater effort put in to get the sand content down by using split stone and sand as virgin aggregates and/or reducing the recycling ratio.
- The reduction in sand content for a given binder content in a mix will increase the binder film thickness and thus mix durability. Also, thicker binder film will generally result in improved compaction and reduce segregation. However, the actual voids in a mix is decreasing from about 50% (in-Spec rate) in 1980 to about 15% in 1984.

Void Content:

- For mix designs, the In-Spec rate was about 60% for the five years.
- However, the actual % In-Spec rate of the plant checks is decreasing from about 50% in 1980 to about 15% in 1984.
- It shows that improved sand content does not necessarily lead to increase in void content. It requires a suitably graded fine aggregate and would fill in the missing gap that alters the void content of a mix. The fine aggregate is therefore job specific and ideally, it should be tailored for each mix design.

Stability:

- The result shows that all mixes have no difficulty in meeting stability requirement.
- The high stability in R.H.M. is a result of the inclusion in a mix of the aged A.C. and crushed aggregate from milling or crushing operation. The aged A.C. has high viscosity and crushed aggregate increased interparticle friction, leading to a reduction in mix workability.

Flow:

- There is a steady increase in % In-Spec rate for the five year period for both the mix design and plant check results. The % In-Spec rate is averaging at 75%.
- The steady improvement in flow could be partly a result of encouraging the use of two grade softer virgin asphalt and introduction of the 500 plus penetration A.C.
- The high stability as mentioned above and low flow indicates that the R.H.M. constructed could be stiff and brittle. These stiff mixes cannot tolerate high pavement deflection as induced by base movements or thermal expansion and contraction.

% VMA:

- The steady increase in % In-Spec rate for the mix design shows that efforts had been made in increasing the VMA during the design stage. However, due to the conditions of the R.A.P. materials similar effort had not yielded the same improvement in the field as seen from the plant check results. The % In-Spec rate for the five year period dropped from about 60% in 1980 to 10% in 1984.

ASPHALT CEMENT PENETRATION

Tables 6 and 7 show the penetration of R.H.M. asphalt cement for different contracts that had the asphalt properties tested at different stages of construction.

The analysis shows that:

(a) Lower than desired level of A.C. penetration still exists for high recycling ratio mixes.

(b) Comparing to "one grade softer" R.H.M., the use of "two grade softer" A.C. had increased the percent of desired penetration from 77% to 90%.

(c) Based on the present system of using softer asphalt cements as rejuvenator, the influence of % R.A.P. on the achievable level of desired penetration can be significant as seen in Fig. 27. For example for 70:30 R.H.M., the average achievable percent of desired penetration is about 57% whereas for a 50:50 R.H.M., it can expect to achieve about 83% of the desired penetration.

(d) It is noted that the apparently high % of desired penetration recorded for 1984 in Table 6 is due to the low recycling ratios (i.e. 30%) used for those contracts.

(e) A correlation was made between field data (Table 7) and the values that were calculated by using a prediction formula developed after laboratory studies on different new A.C. and recovered A.C. from R.A.P. The formula for predicting the final penetration of the asphalt cement in the R.H.M. pavement is as follows:

$$\log Pp = 1/z\ (x \log (Cao\ Po) + y \log (Can\ Pn)$$

Where: Pp = Predicted penetration of RHM.

Po = Penetration of recovered A.C. from RAP

Pn = Penetration of virgin A.C.

z = % A.C. in RHM

x = % of recovered A.C. from the RAP in a RHM

= (% RAP x % recovered A.C.)/100

y = % of virgin A.C. added to RHM

= z - x.

Cao = Aging factor of old asphalt (= 0.72)

Can = Aging factor of virgin asphalt (see App.4)

For 70:30 use 0.40

60:40 ... 0.49

50:50 ... 0.53

40:60 ... 0.54

30:70 ... 0.55

The correlation between field data and the predicted values is good having a correlation coefficient of 0.88. This formula can be also used to determine the grade of virgin A.C. required or to examine whether a certain proportion of RAP can be used in a RHM (Appendix 4) given that a certain desired penetration has to be achieved..

CONCLUSIONS

1. Stone contents in RHM continue to improve recognizing that high sand content mixes will have difficulties in meeting specification and construction requirements. Generally sand contents are high in Southwestern, Northern and Northwestern regions with Central and Eastern region within the 55 to 60% desirable range.

2. A large number of mixes fell short of meeting void content requirements by about 1%, especially in the years of 1983 and 1984. Only about 20% of the RHM met voids specifications in those two years.

3. Stability of RHM was high and had no difficulty in meeting specification. However, there were some 20% of the mixes with low flow values. These types of mixes could be brittle.

4. In comparison with other regions, Central Region had the largest difference in average flow value between mix designs and plant checks. The cause of the large differences may warrant some investigation.

5. Mix design VMA results continue to improve showing about 35% of the mixes achieving the specification minimum. The field results however show otherwise, i.e. a downward trend over the five years. Most mixes which did not meet the specifications were less than one and a half percent below the minimum requirement.

6. For high recycling ratio mixes, lower than desired A.C. penetration was obtained. On the other hand, by using an A.C. two-grade softer than "standard", it is more likely to achieve the desired A.C. penetration than with one-grade softer A.C.

7. The influence of percent RAP (i.e. recycling ratio) on the achievable level of desired penetration is significant (Fig. 27).

8. The formula developed, based on field data and laboratory evaluation, provides a method which can reliably predict the penetration of asphalt

cement in the RHM or the pavement. The formula can be also used for determining the grade of virgin A.C. required or to check if the recycling proportion used would give the level of desired penetration in the RHM.

Recommendations

After reviewing the mix property data and in order to address the current issues of questionable RHM quality, difficulties in meeting specification requirements and potential performance problems, the following recommendations are made. The feasibility of implementing some of these recommendations should be examined in conjunction with economic terms.

1. Continue to improve the quality of asphalt cement and mixture by:
   - (a) The use of 'super-soft' asphalt as virgin A.C. (Special care is needed as it may encourage flushing in sensitive mixes)
   - (b) Checking the desirable A.C. penetration of RHM projects using the formula developed.
   - (c) Considering the use of more effective recycling/rejuvenating agents.
   - (d) Lowering of recycling ratio.
   - (e) Specifying a range of A.C. penetration requirements based on experience gained on standard asphalt mixtures.

2. Thicker lifts (e.g. 50 mm per lift) of RHM should be considered to reduce or eliminate laying temperatures and segregation problems. This will also reduce the chance of tearing the mat by oversize materials and allow for greater use of reclaimed materials to alleviate the problems of surplus RAP.

3. The current MTC procedure and specification standard should be followed for RHM placed as surface course and thin pavements (<90 mm).

4. For roads with light traffic and low truck count, changes in the number of Marshall blows during mix design should be considered for both RHM and virgin mixes.

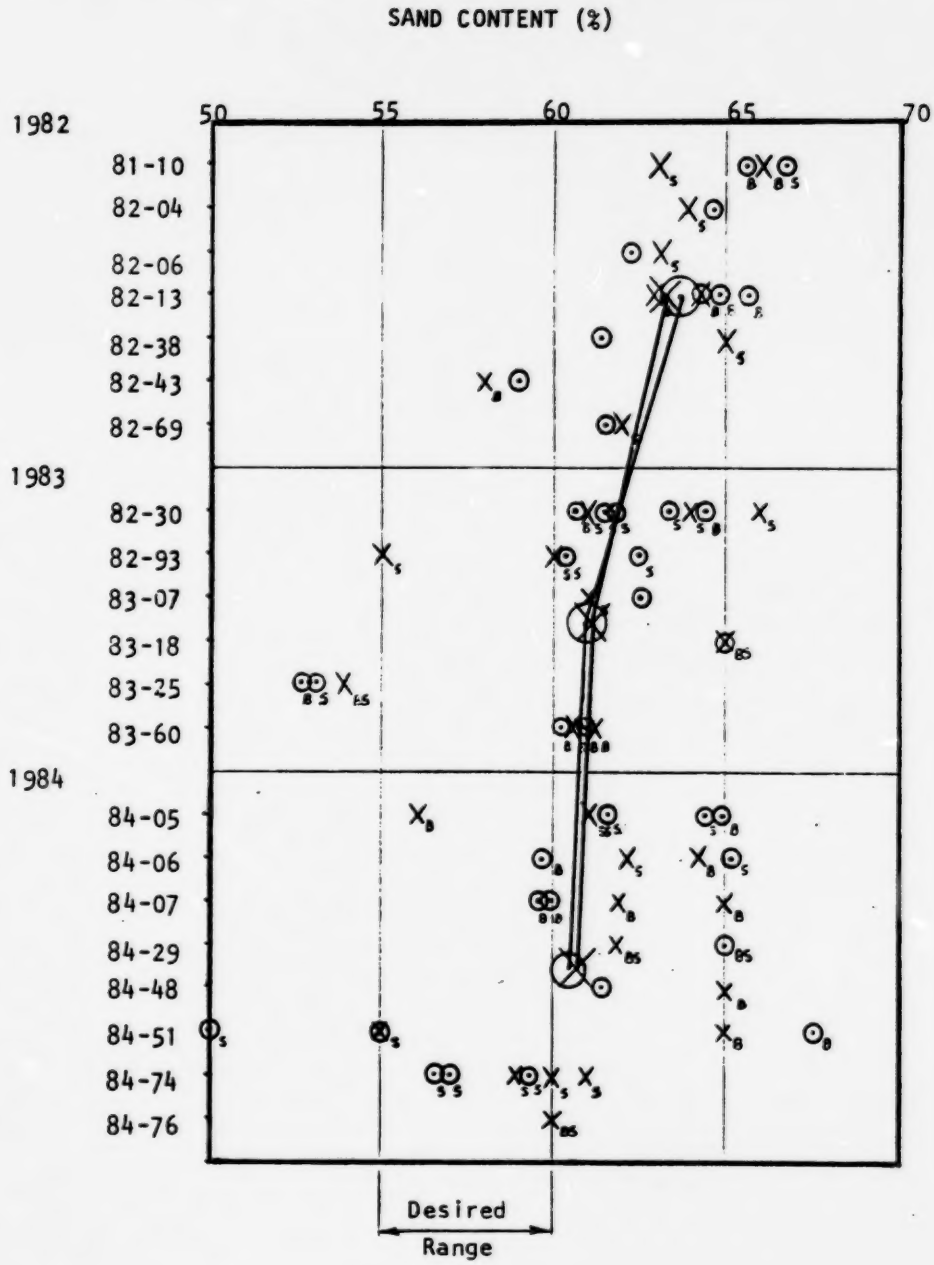
5. Another round of evaluation of data should be carried out in 1987 to assess the impact of any future changes. Also in the evaluation, overall field performance of RHM should be reviewed in relation to mix selection data recorded in this report (by then there will be eight years of experience).

# TABLE 1

## ANALYSIS OF SAND CONTENT RESULTS

| TYPE | LIFT | REGION | AVERAGE | | | | | RANGE | | | | | % IN - SPEC. | | | | | NO. OF MIXES MONITORED | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1980 | 1981 | 1982 | 1983 | 1984 | 1980 | 1981 | 1982 | 1983 | 1984 | 1980 | 1981 | 1982 | 1983 | 1984 | 1980 | 1981 | 1982 | 1983 | 1984 |
| MIX DESIGN | Surf. | S.W. | - | - | 63.5 | 61.7 | 59.6 | - | - | 62-65 | 54-66 | 59-62.1 | - | - | 0 | 20 | 55 | 0 | 0 | 5 | 10 | 11 |
| | | C. | - | - | 55 | 54.6 | 55 | - | - | 55 | 50-57.5 | 55 | - | - | 100 | 83 | 100 | 0 | 0 | 2 | 6 | 1 |
| | | E. | 55.5 | - | 57 | - | 61.4 | 52-59 | - | 50-60 | - | 61.4 | 50 | - | 67 | - | 0 | 2 | 0 | 6 | 0 | 1 |
| | | N. | 65 | 57.2 | 59.8 | 59.4 | 55.5 | 65 | 56-58 | 57-64 | 59.4 | 49.7-57.8 | 0 | 100 | 60 | 100 | 80 | 1 | 6 | 5 | 1 | 5 |
| | | N.W. | 60 | 60.3 | 59.9 | 59.4 | 57 | 60 | 59-65 | 57-62 | 55-65 | 55-60 | 100 | 92 | 86 | 88 | 100 | 2 | 12 | 7 | 8 | 4 |
| | | PROV. | 59.2 | 59.2 | 59.5 | 59.2 | 58.1 | 52-65 | 56-65 | 50-65 | 54-66 | 49.7-62.1 | 60 | 94 | 68 | 60 | 68 | 5 | 18 | 25 | 25 | 22 |
| | Bind. | S.W. | - | - | 62.8 | 60.3 | 62.7 | - | - | 58-66 | 54-65 | 56-65 | - | - | 25 | 20 | 14 | 0 | 0 | 4 | 5 | 7 |
| | | C. | - | - | 55 | 55.4 | 55.6 | - | - | 50-60 | 50-60 | 55-60 | - | - | 86 | 86 | 100 | 0 | 0 | 7 | 7 | 9 |
| | | E. | - | 57 | 55 | - | 58.6 | - | 57 | 50-60 | - | 55.7-61.4 | - | 100 | 50 | - | 50 | 0 | 1 | 2 | 0 | 2 |
| | | N. | 58.5 | 59.3 | 59 | 59.4 | 56.4 | 57-62 | 57-64 | 58-60 | 59.4 | 51.3-59.7 | 75 | 67 | 100 | 100 | 71 | 4 | 3 | 4 | 1 | 7 |
| | | N.W. | 61.7 | 61.6 | 58.3 | 58 | 59.8 | 60-65 | 55-65 | 55-60 | 55-60 | 58-61.5 | 67 | 50 | 100 | 100 | 67 | 3 | 8 | 3 | 6 | 3 |
| | | PROV. | 59.8 | 60.6 | 57.9 | 57.7 | 58.2 | 57-65 | 55-65 | 50-66 | 50-65 | 51.3-65 | 71 | 58 | 75 | 74 | 64 | 7 | 12 | 20 | 19 | 28 |
| PLANT CHECKS | Surf. | S.W. | - | - | 63.3 | 61.7 | 59.3 | - | - | 61.5-66.4 | 53-65 | 50-65.1 | - | - | 0 | 0 | 50 | 0 | 0 | 5 | 10 | 10 |
| | | C. | - | - | 56.7 | 54.8 | 55.5 | - | - | 53.2-56.1 | 50.3-58.2 | 53.8-57.2 | - | - | 50 | 50 | 50 | 0 | 0 | 2 | 6 | 2 |
| | | E. | 58.8 | - | 58.7 | - | 59.3 | 54-63.5 | - | 55.8-61.3 | - | 59.3 | 50 | - | 83 | - | 100 | 2 | 0 | 6 | 0 | 1 |
| | | N. | 64 | 59.5 | 58.4 | 62.6 | 55.5 | 64 | 55.3-62.5 | 54.4-61.2 | 62.6 | 49.4-58.8 | 0 | 50 | 60 | 0 | 71 | 1 | 6 | 5 | 1 | 7 |
| | | N.W. | 60.3 | 62.8 | 60.6 | 61.3 | 59.2 | 58.7-61.9 | 60.1-65.2 | 58.4-62.7 | 57.3-68.5 | 56.7-62.9 | 50 | 0 | 29 | 38 | 50 | 2 | 12 | 7 | 8 | 4 |
| | | PROV. | 60.4 | 61.7 | 59.9 | 60.0 | 57.9 | 54-64 | 55.3-65.2 | 53.2-66.4 | 50.3-68.5 | 49.4-65.1 | 40 | 17 | 44 | 24 | 58 | 5 | 18 | 25 | 25 | 24 |
| | Bind. | S.W. | - | - | 63.9 | 59.9 | 62.6 | - | - | 59-65.7 | 52.9-65 | 59.6-67.9 | - | - | 20 | 0 | 43 | 0 | 0 | 5 | 5 | 7 |
| | | C. | - | - | 56.3 | 59.6 | 55 | - | - | 53.1-59.9 | 49-61.3 | 51.9-59.4 | - | - | 57 | 44 | 44 | 0 | 0 | 7 | 9 | 9 |
| | | E. | - | 61.1 | 59.1 | - | 58.8 | - | 61.1 | 58.4-59.8 | - | 58.8 | - | 0 | 100 | - | 100 | 0 | 1 | 2 | 0 | 1 |
| | | N. | 62.5 | 62.7 | 60.1 | 64.5 | 59.3 | 62.5 | 62-63.7 | 57.9-63.7 | 64.5 | 50.7-65.1 | 25 | 0 | 75 | 0 | 33 | 4 | 3 | 4 | 1 | 6 |
| | | N.W. | 63.5 | 60.7 | 61.5 | 59.5 | 60.6 | 59.1-67.8 | 55-64.1 | 59.9-63 | 56.9-61.3 | 58.4-63.4 | 33 | 13 | 33 | 50 | 67 | 3 | 8 | 3 | 6 | 3 |
| | | PROV. | 62.9 | 61.2 | 59.8 | 57.7 | 58.8 | 59.1-67.8 | 55-64.1 | 53.1-65.7 | 49-65 | 50.7-67.9 | 29 | 8 | 52 | 33 | 46 | 7 | 12 | 21 | 21 | 26 |

SOUTHWESTERN REGION




X = Mix Design
⊙ = Plant Check
s = Surface Course
B = Binder Course

= Annual Mix Design Average
= Annual Plant Check Average

FIG. 1

CENTRAL REGION

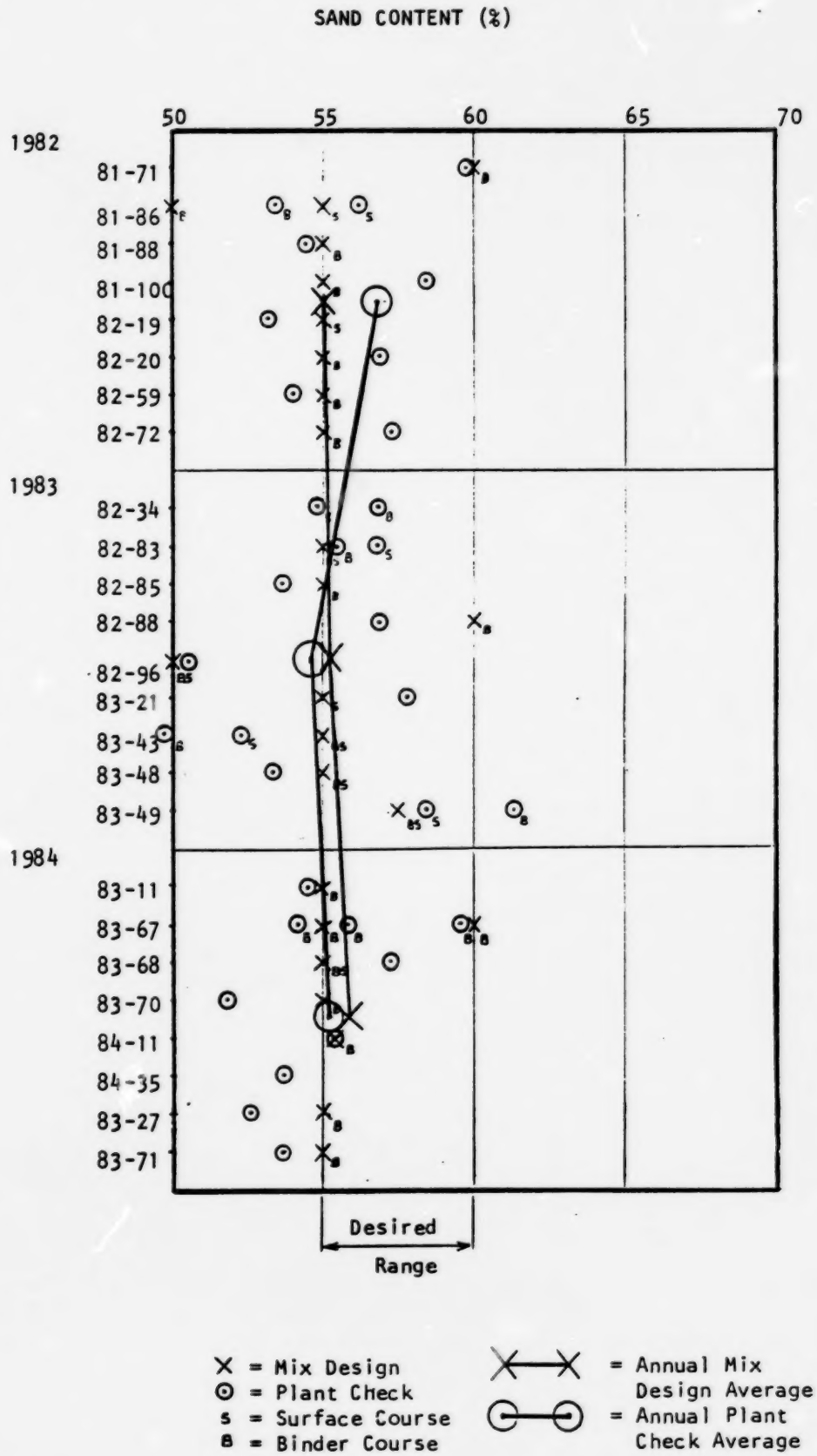
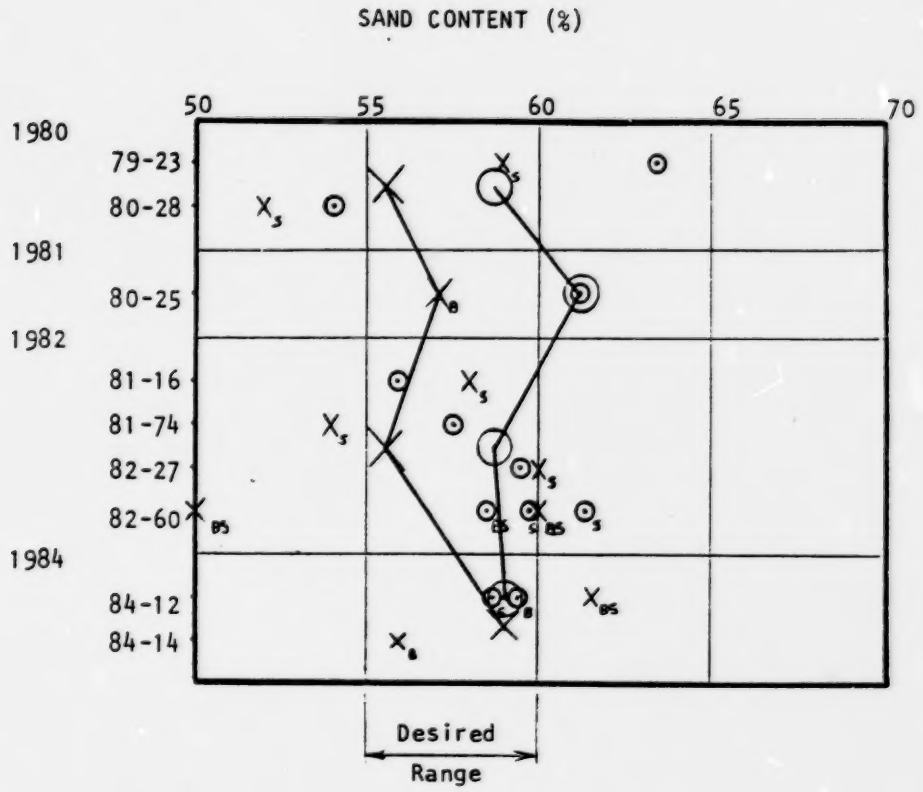



FIG. 2

EASTERN REGION

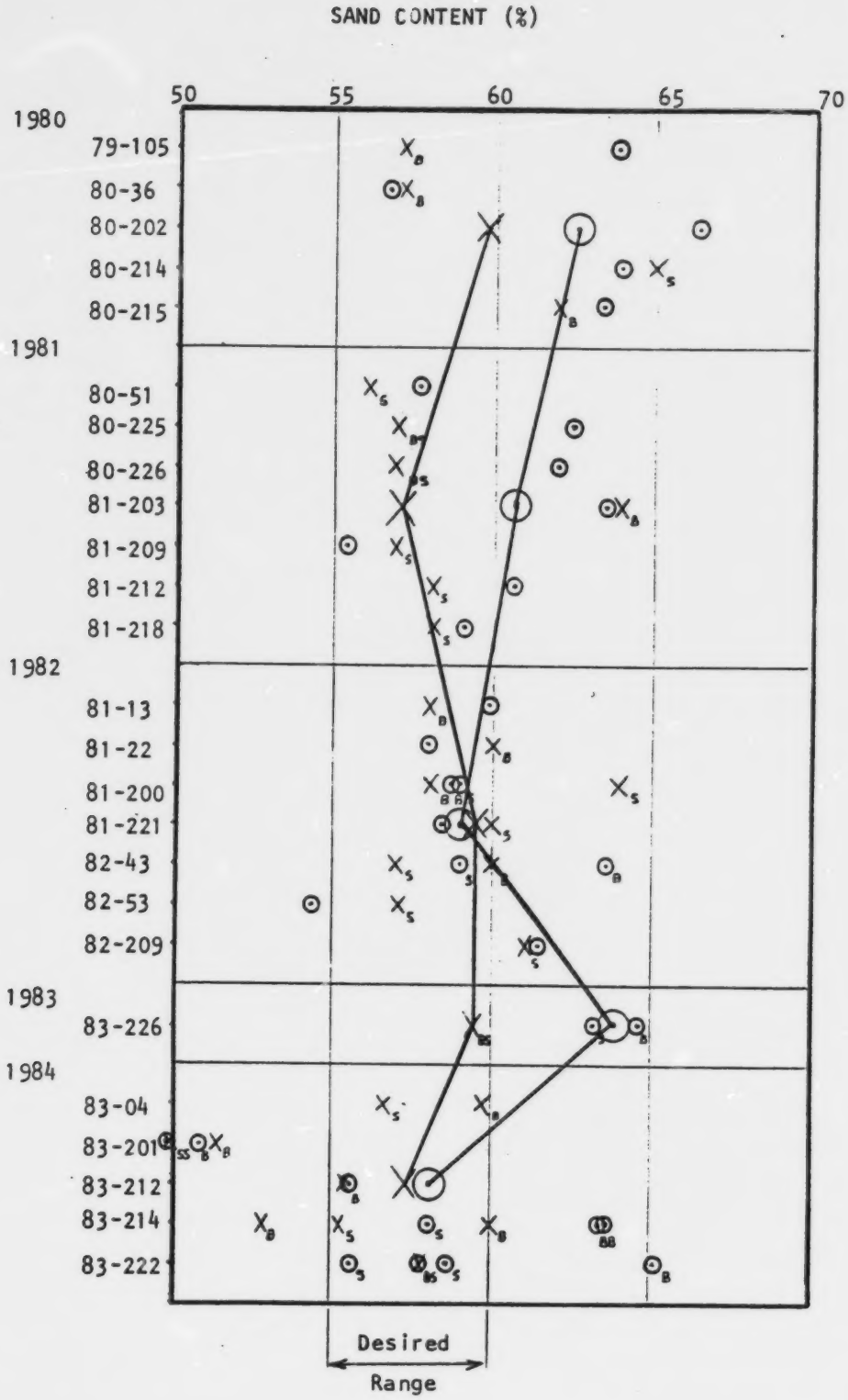



X = Mix Design
⊙ = Plant Check
s = Surface Course
b = Binder Course

= Annual Mix Design Average
= Annual Plant Check Average

FIG. 3

NORTHERN REGION




X = Mix Design
⊙ = Plant Checks
s = Surface Course
B = Binder Course

= Annual Mix Design Average

= Annual Plant Check Average

FIG. 4

NORTHWESTERN REGION

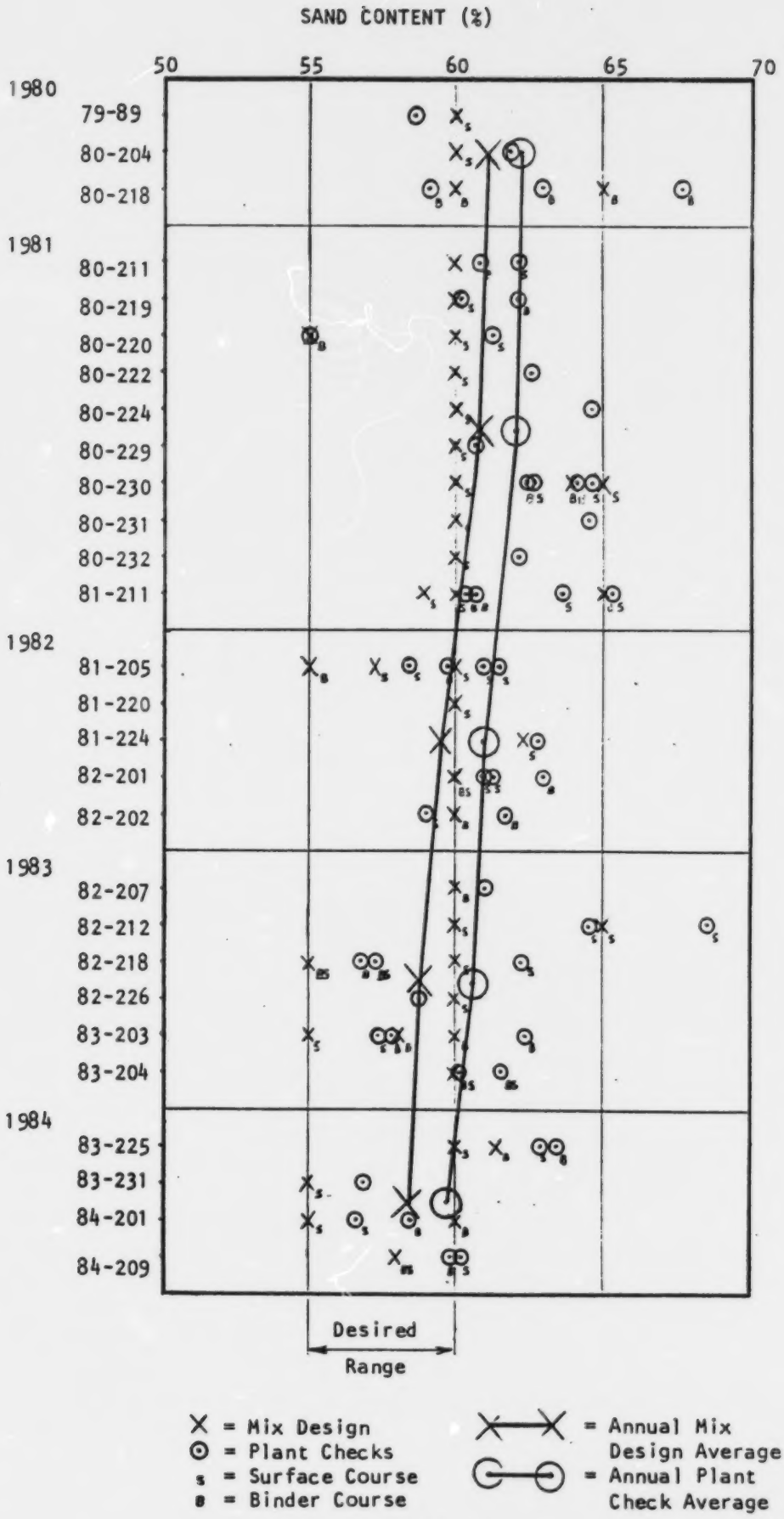


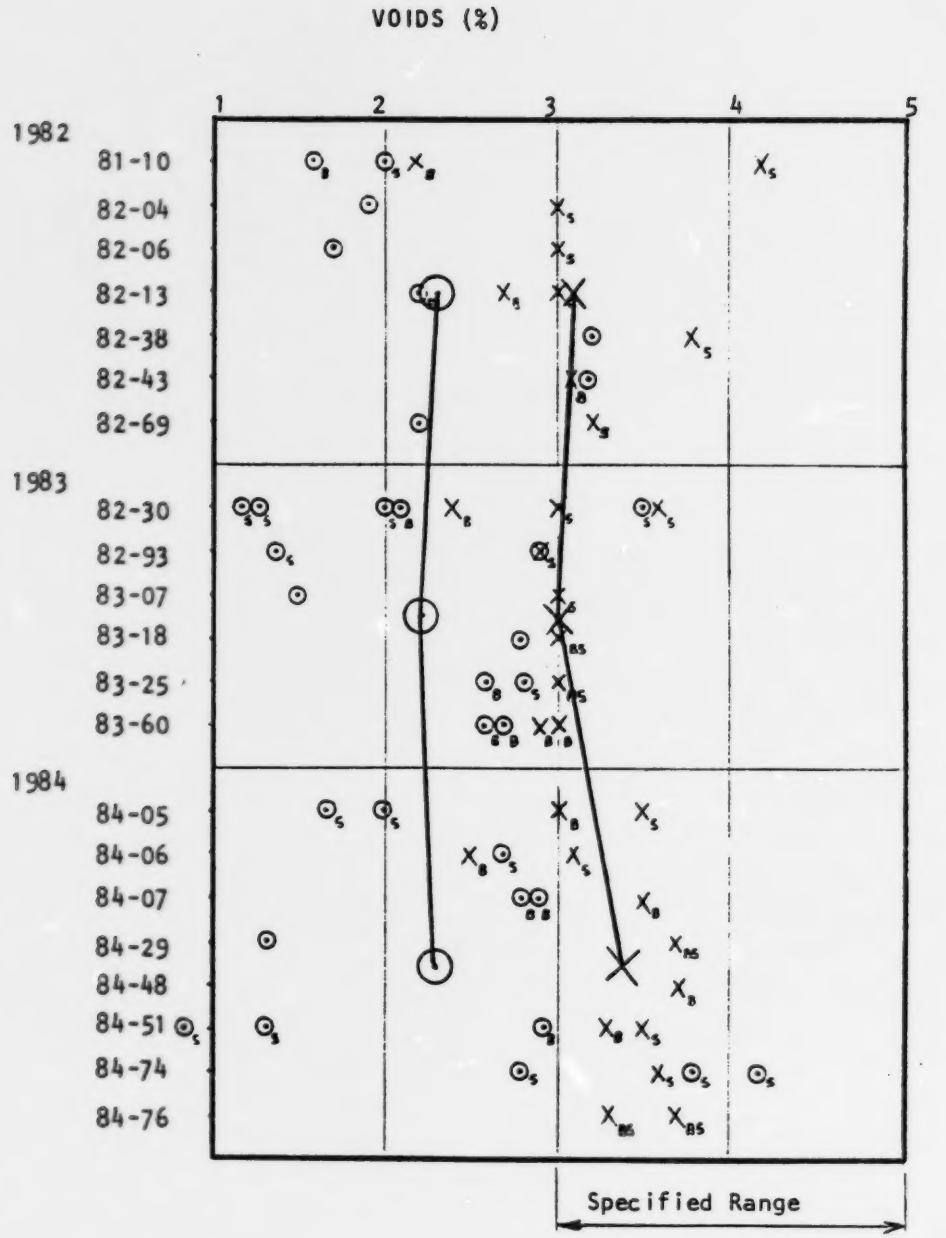

FIG. 5

# TABLE 2

## ANALYSIS OF AIR VOIDS (%) RESULTS

| TYPE | LIFT | REGION | AVERAGE | | | | | RANGE | | | | | %IN - SPEC. | | | | | NO. OF MIXES MONITORED | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1980 | 1981 | 1982 | 1983 | 1984 | 1980 | 1981 | 1982 | 1983 | 1984 | 1980 | 1981 | 1982 | 1983 | 1984 | 1980 | 1981 | 1982 | 1983 | 1984 |
| MIX DESIGN | Surf. | S.W. | - | - | 3.4 | 3.1 | 3.5 | - | - | 3-4.2 | 2.9-3.6 | 3.1-3.7 | - | - | 100 | 75 | 100 | 0 | 0 | 5 | 8 | 10 |
| | | C. | - | - | 2.5 | 2.8 | 1.7 | - | - | 2.2-2.8 | 2-3.5 | 1.7 | - | - | 0 | 40 | 0 | 0 | 0 | 2 | 5 | 1 |
| | | E. | 2.7 | - | 3.1 | - | 3.5 | 2.4-2.7 | - | 2.3-3.5 | - | 3.5 | 50 | - | 83 | - | 0 | 2 | - | 6 | - | 1 |
| | | N. | 3 | 3.3 | 3.5 | 3.2 | 2.7 | 3 | 3-3.6 | 3.3-3.5 | 3.2 | 2-3.6 | 100 | 100 | 100 | 100 | 40 | 1 | 6 | 5 | 1 | 5 |
| | | N.W. | 3.5 | 3.1 | 3.0 | 3.3 | 3.5 | 3.3-3.7 | 2.5-3.5 | 2.6-3.3 | 2.7-3.8 | 2.8-4 | 100 | 73 | 50 | 67 | 75 | 2 | 11 | 6 | 6 | 4 |
| | | PROV. | 3.1 | 3.2 | 3.2 | 3.1 | 3.2 | 2.4-3.7 | 2.5-3.6 | 2.2-4.2 | 2-3.8 | 1.7-4 | 80 | 82 | 75 | 65 | 71 | 5 | 17 | 24 | 20 | 21 |
| | Bind. | S.W. | - | - | 2.8 | 2.9 | 3.3 | - | - | 2.2-3.1 | 2.4-3 | 2.5-3.7 | - | - | 50 | 60 | 86 | 0 | 0 | 4 | 5 | 7 |
| | | C. | - | - | 1.6 | 2.2 | 2.1 | - | - | 1.3-2.2 | 1.3-2.8 | 1.7-2.3 | - | - | 0 | 0 | 0 | 0 | 0 | 7 | 7 | 5 |
| | | E. | - | 2.9 | 3.1 | - | 3.1 | - | 2.9 | 3-3.1 | - | 3-3.2 | - | 0 | 100 | - | 100 | 0 | 1 | 2 | 0 | 2 |
| | | N. | 2.8 | 3.0 | 3.0 | 3.2 | 2.7 | 2.4-3.5 | 2.7-3.2 | 1.9-3.4 | 3.2 | 2-3.2 | 25 | 67 | 75 | 100 | 43 | 4 | 3 | 4 | 1 | 7 |
| | | N.W. | 3.7 | 2.8 | 2.7 | 3.2 | 3.5 | 3.2-4 | 2.3-3.5 | 2.5-3 | 2.6-3.8 | 2.8-3.8 | 100 | 38 | 33 | 67 | 67 | 3 | 8 | 3 | 6 | 3 |
| | | PROV. | 3.2 | 2.9 | 2.4 | 2.8 | 2.9 | 2.4-4 | 2.3-[illegible] | 1.9-3.4 | 1.3-3.8 | 1.7-3.8 | 57 | 42 | 40 | 42 | 54 | 7 | 12 | 20 | 19 | 24 |
| PLANT CHECKS | Surf. | S.W. | - | - | 2.2 | 2.0 | 2.2 | - | - | 1.7-3.2 | 1.2-3.5 | .8-4.2 | - | - | 20 | 10 | 20 | 0 | 0 | 5 | 10 | 10 |
| | | C. | - | - | 1.4 | 2.1 | 2.9 | - | - | 1-1.7 | .3-2.9 | 1.8-3.9 | - | - | 0 | 0 | 50 | 0 | 0 | 2 | 6 | 2 |
| | | E. | 2.1 | - | 3.1 | - | 2.5 | 1.8-2.4 | - | 2.6-3.4 | - | 2.5 | 0 | - | 57 | - | 0 | 2 | 0 | 7 | 0 | 1 |
| | | N. | 4 | 3.4 | 3.6 | 2.7 | 2.1 | 4 | 2.6-4.8 | 2.7-4.8 | 2.7 | 1.3-3 | 100 | 86 | 80 | 0 | 25 | 1 | 6 | 5 | 1 | 4 |
| | | N.W. | 3.4 | 2.6 | 3.2 | 3.4 | 3.2 | 2.5-4.2 | 1.3-3.7 | 2.3-3.9 | 2.4-4.6 | 2.6-3.9 | 50 | 42 | 71 | 63 | 75 | 2 | 12 | 7 | 8 | 4 |
| | | PROV. | 3 | 2.9 | 2.9 | 2.5 | 2.5 | 1.8-4.2 | 1.3-4.8 | 1-4.1 | .3-4.6 | .8-4.2 | 40 | 56 | 54 | 24 | 33 | 5 | 18 | 26 | 25 | 21 |
| | Bind. | S.W. | - | - | 2.3 | 2.6 | 2.5 | - | - | 1.6-3.2 | 2.1-2.8 | 1.3-2.9 | - | - | 20 | 0 | 0 | 0 | 0 | 5 | 5 | 4 |
| | | C. | - | - | 1.8 | 1.6 | 1.6 | - | - | 1-3.3 | .9-2.9 | .8-2 | - | - | 14 | 0 | 0 | 0 | 0 | 7 | 9 | 9 |
| | | E. | - | 2.3 | 4 | - | 2.6 | - | 2.3 | 3.3-4.7 | - | 2.6 | - | 0 | 100 | - | 0 | 0 | 1 | 2 | 0 | 1 |
| | | N. | 2.9 | 3.5 | 3.0 | 3.4 | 2.6 | 2.4-3.5 | 2.5-4.8 | 2.6-3.3 | 3.4 | 1.4-3.7 | 25 | 67 | 50 | 100 | 33 | 4 | 3 | 4 | 1 | 6 |
| | | N.W. | 3.5 | 2.9 | 2.3 | 3.2 | 2.6 | 2.7-4.9 | 2.4-3.6 | 1.8-2.8 | 2-4.8 | 2-3.2 | 33 | 38 | 0 | 50 | 33 | 3 | 8 | 3 | 6 | 3 |
| | | PROV. | 3.2 | 2.8 | 2.4 | 2.4 | 2.2 | 2.4-4.9 | 2.3-4.8 | 1-4.7 | .9-4.8 | .8-3.7 | 29 | 42 | 29 | 19 | 13 | 7 | 12 | 21 | 21 | 23 |

SOUTHWESTERN REGION




X = Mix Design
⊙ = Plant Check
s = Surface Course
B = Binder Course

X—X = Annual Mix Design Average
⊙—⊙ = Annual Plant Check Average

FIG. 6

CENTRAL REGION

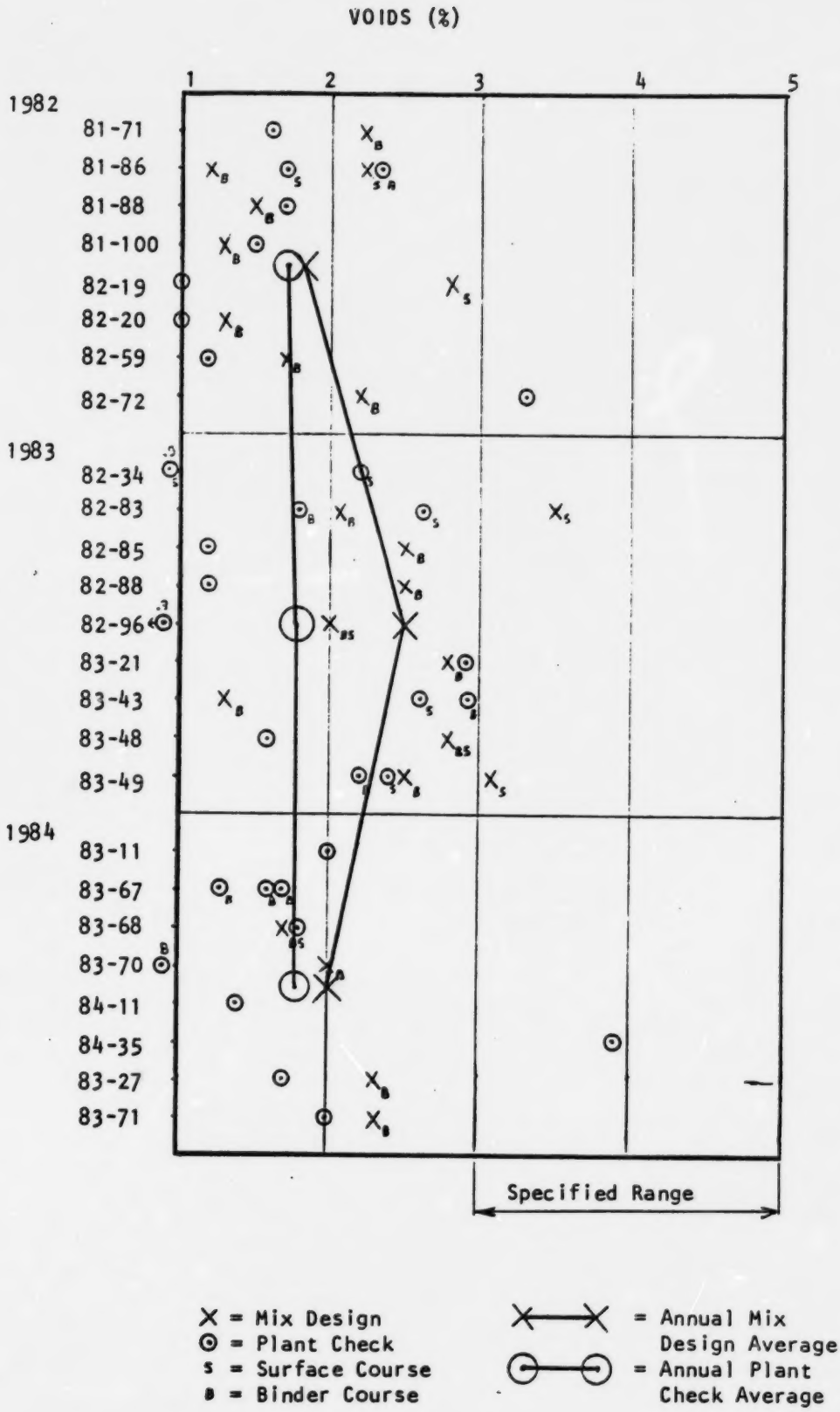



FIG. 7

EASTERN REGION

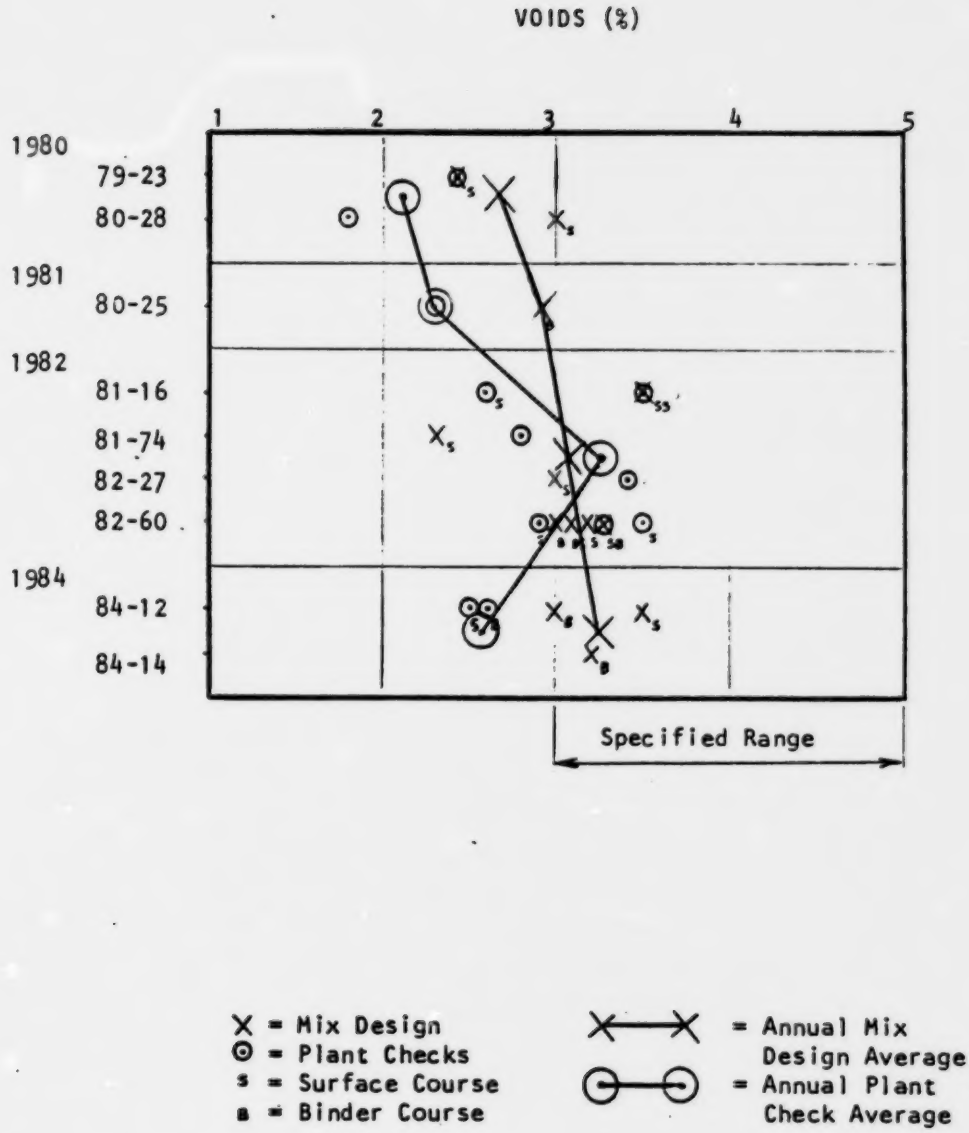



FIG. 8

NORTHERN REGION

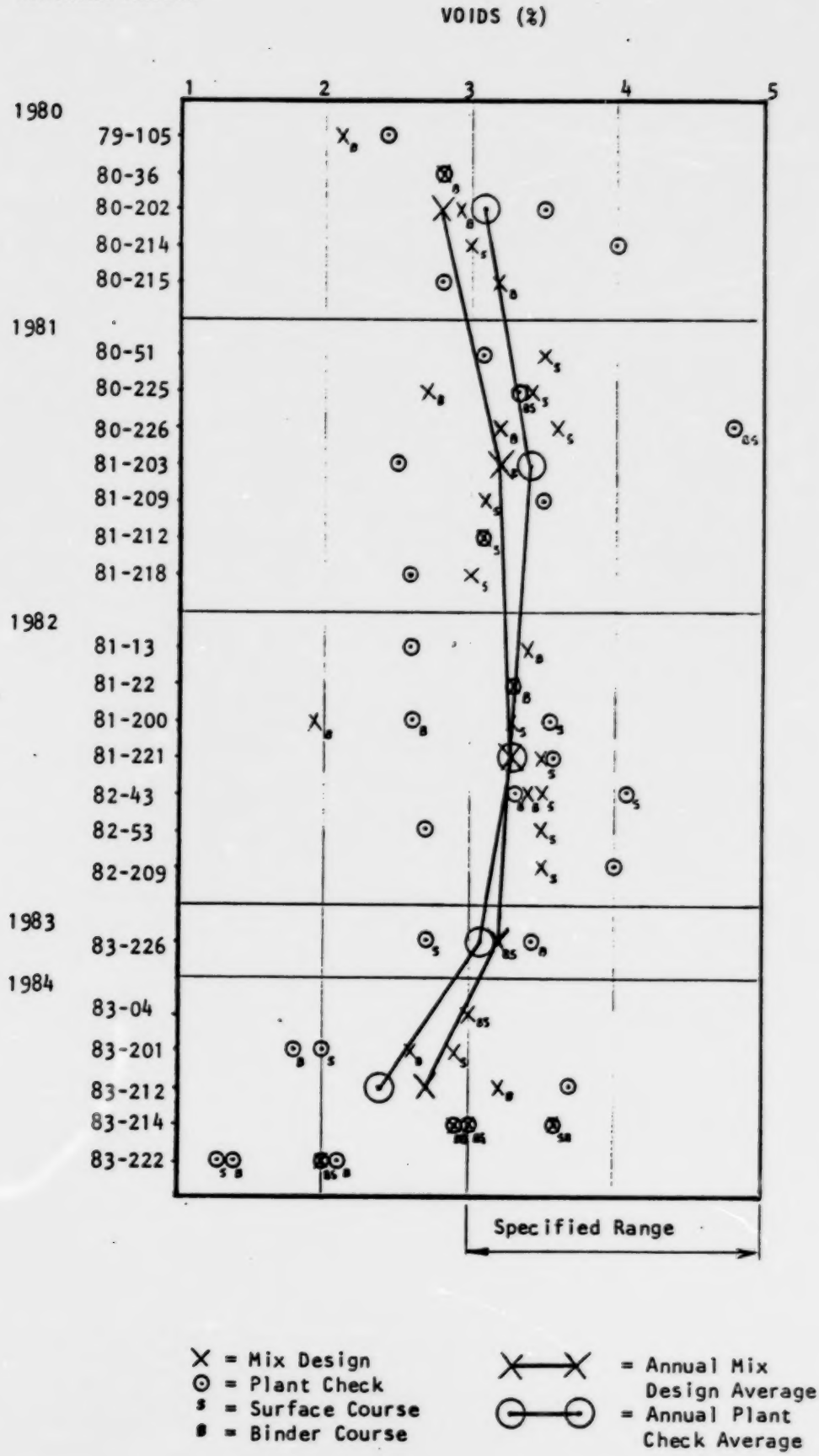



FIG. 9

NORTHWESTERN REGION

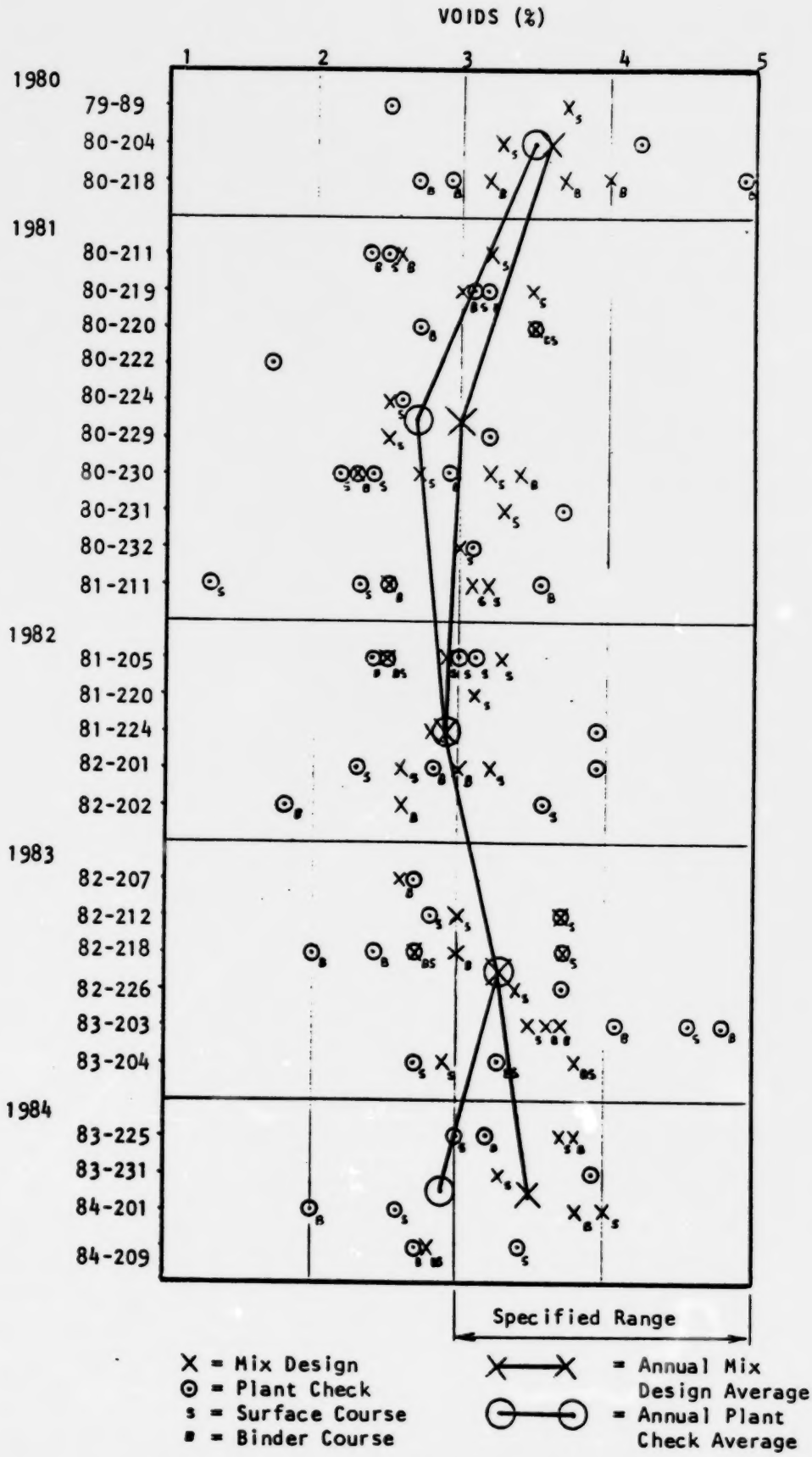



FIG. 10

# TABLE 3

## ANALYSIS OF MARSHALL FLOW RESULTS

| TYPE | LIFT | REGION | AVERAGE | | | | | RANGE | | | | | % IN - SPEC. | | | | | NO. OF MIXES MONITORED | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1980 | 1981 | 1982 | 1983 | 1984 | 1980 | 1981 | 1982 | 1983 | 1984 | 1980 | 1981 | 1982 | 1983 | 1984 | 1980 | 1981 | 1982 | 1983 | 1984 |
| MIX DESIN | Surf. | S.W. | - | - | 12.4 | 12.9 | 10.9 | - | - | 10.2-13.8 | 9-15.5 | 9.8-12.2 | - | - | 100 | 88 | 100 | 0 | 0 | 5 | 8 | 10 |
| | | C. | - | - | 18.8 | 11.0 | 11.2 | - | - | 10.2-27.4 | 9.8-13 | 11.2 | - | - | 100 | 80 | 100 | 0 | 0 | 2 | 5 | 1 |
| | | E. | 15 | - | 9.1 | - | 9.4 | 13.2-16.7 | - | 8-11.5 | - | 9.4 | 100 | - | 17 | - | 0 | 2 | 0 | 6 | 0 | 1 |
| | | N. | 12.1 | 11.8 | 11.5 | 10.6 | 13.2 | 12.1 | 10.8-13.1 | 9.7-13.7 | 10.6 | 11.3-15.8 | 100 | 100 | 80 | 100 | 100 | 1 | 6 | 5 | 1 | 5 |
| | | N.W. | 9.7 | 11.2 | 10.9 | 10.1 | 9.2 | 9-10.3 | 8.2-13.2 | 8.3-13 | 8-11.7 | 8.4-10.9 | 50 | 82 | 50 | 63 | 25 | 2 | 11 | 6 | 8 | 4 |
| | | PROV. | 12.3 | 11.4 | 11.5 | 11.3 | 11.1 | 9-16.7 | 8.2-13.2 | 8-27.4 | 8-15.5 | 8.4-15.8 | 80 | 88 | 63 | 77 | 81 | 5 | 17 | 24 | 22 | 21 |
| | Bind. | S.W. | - | - | 12.9 | 12.4 | 11.0 | - | - | 10.3-18 | 11.2-14.9 | 9.8-12.8 | - | - | 100 | 100 | 86 | 0 | 0 | 4 | 5 | 7 |
| | | C. | - | - | 15.4 | 12.9 | 11.8 | - | - | 11.1-21.3 | 10.6-21.5 | 11.2-13.2 | - | - | 100 | 100 | 100 | 0 | 0 | 7 | 7 | 5 |
| | | E. | - | 10.6 | 9.8 | - | 9.4 | - | 10.6 | 8.9-10.7 | - | 9.2-9.6 | - | 100 | 50 | - | 0 | 0 | 1 | 2 | 0 | 2 |
| | | N. | 12.6 | 12.9 | 13.0 | 10.6 | 12.8 | 11.8-13.3 | 12-13.5 | 11.2-14.7 | 10.6 | 10.7-15.8 | 100 | 100 | 100 | 100 | 100 | 4 | 3 | 4 | 1 | 6 |
| | | N.W. | 9.2 | 11.5 | 12.2 | 9.9 | 9.5 | 8.6-9.8 | 10.2-14.6 | 11.3-12.8 | 8-11 | 8.4-10.6 | 0 | 100 | 100 | 67 | 33 | 3 | 8 | 3 | 6 | 3 |
| | | PROV. | 11.1 | 11.8 | 13.4 | 11.7 | 11.3 | 8.6-13.3 | 10.2-14.6 | 8.9-21.3 | 8-21.5 | 8.4-15. | 57 | 100 | 95 | 89 | 78 | 7 | 12 | 20 | 19 | 23 |
| PLANT CHECKS | Surf. | S.W. | - | - | 12.0 | 14.4 | 10.7 | - | - | 10.9-13.1 | 11-20.5 | 8.4-12.9 | - | - | 100 | 100 | 70 | 0 | 0 | 5 | 10 | 10 |
| | | C. | - | - | 17.1 | 14.3 | 17.7 | - | - | 14.2-19.9 | 11.2-20.1 | 11.7-23.6 | - | - | 100 | 100 | 100 | 0 | 0 | 2 | 6 | 2 |
| | | E. | 15.8 | - | 9.5 | - | 12.4 | 14-17.5 | - | 7.9-12.1 | - | 12.4 | 100 | - | 43 | - | 100 | 2 | 0 | 7 | 0 | 1 |
| | | N. | 10.5 | 11.5 | 11.7 | 10.8 | 12.5 | 10.5 | 9.5-13.9 | 11-13.4 | 10.8 | 10.9-13 | 100 | 86 | 100 | 100 | 100 | 1 | 6 | 5 | 1 | 4 |
| | | N.W. | 11 | 12.6 | 12.3 | 9.5 | - | 9.1-12.9 | 9.9-15.5 | 11.4-13.2 | 7.4-11.3 | - | 50 | 75 | 100 | 25 | - | 2 | 12 | 4 | 8 | 0 |
| | | PROV. | 12.8 | 12.2 | 11.7 | 12.7 | 12.0 | 9.1-17.5 | 9.5-15.5 | 7.9-19.9 | 7.4-20.5 | 8.4-23.6 | 80 | 78 | 87 | 76 | 82 | 5 | 18 | 23 | 25 | 17 |
| | Bind. | S.W. | - | - | 12.6 | 12.6 | 10.4 | - | - | 10.7-16.8 | 9.3-19.6 | 7.7-12.9 | - | - | 100 | 60 | 75 | 0 | 0 | 5 | 5 | 4 |
| | | C. | - | - | 14.5 | 15.4 | 14.3 | - | - | 11-17.9 | 12.3-20.1 | 11.6-22 | - | - | 100 | 100 | 100 | 0 | 0 | 7 | 9 | 9 |
| | | E. | - | 13.6 | 8.8 | - | 12.4 | - | 13.6 | 8.6-8.9 | - | 12.4 | - | 100 | 0 | - | 100 | 0 | 1 | 2 | 0 | 1 |
| | | N. | 13.5 | 12 | 12.3 | 10.2 | 12.6 | 13.1-13.7 | 11.5-13 | 11.1-13.5 | 10.2 | 11.4-14 | 100 | 100 | 100 | 100 | 100 | 4 | 3 | 4 | 1 | 6 |
| | | N.W. | 9.3 | 10.7 | 15.3 | 10.5 | - | 8.6-10.2 | 9.7-12 | 15.3 | 8.5-12.9 | - | 33 | 63 | 100 | 67 | - | 3 | 8 | 1 | 6 | 0 |
| | | PROV. | 11.6 | 11.3 | 13.0 | 13.1 | 12.9 | 8.6-13.7 | 9.7-13.6 | 8.6-17.9 | 8.5-20.1 | 7.7-22 | 71 | 75 | 89 | 76 | 95 | 7 | 12 | 19 | 21 | 20 |

SOUTHWESTERN REGION

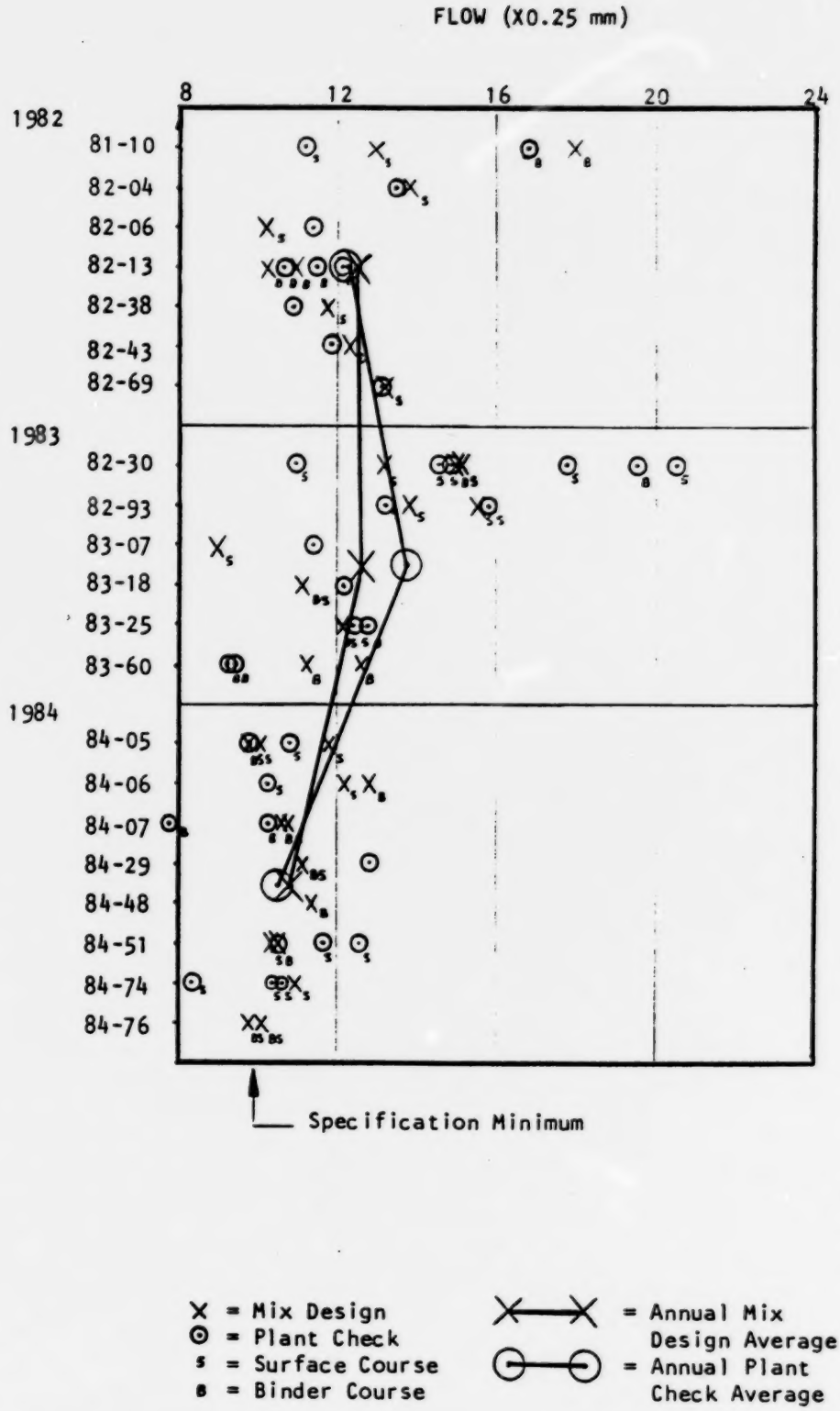
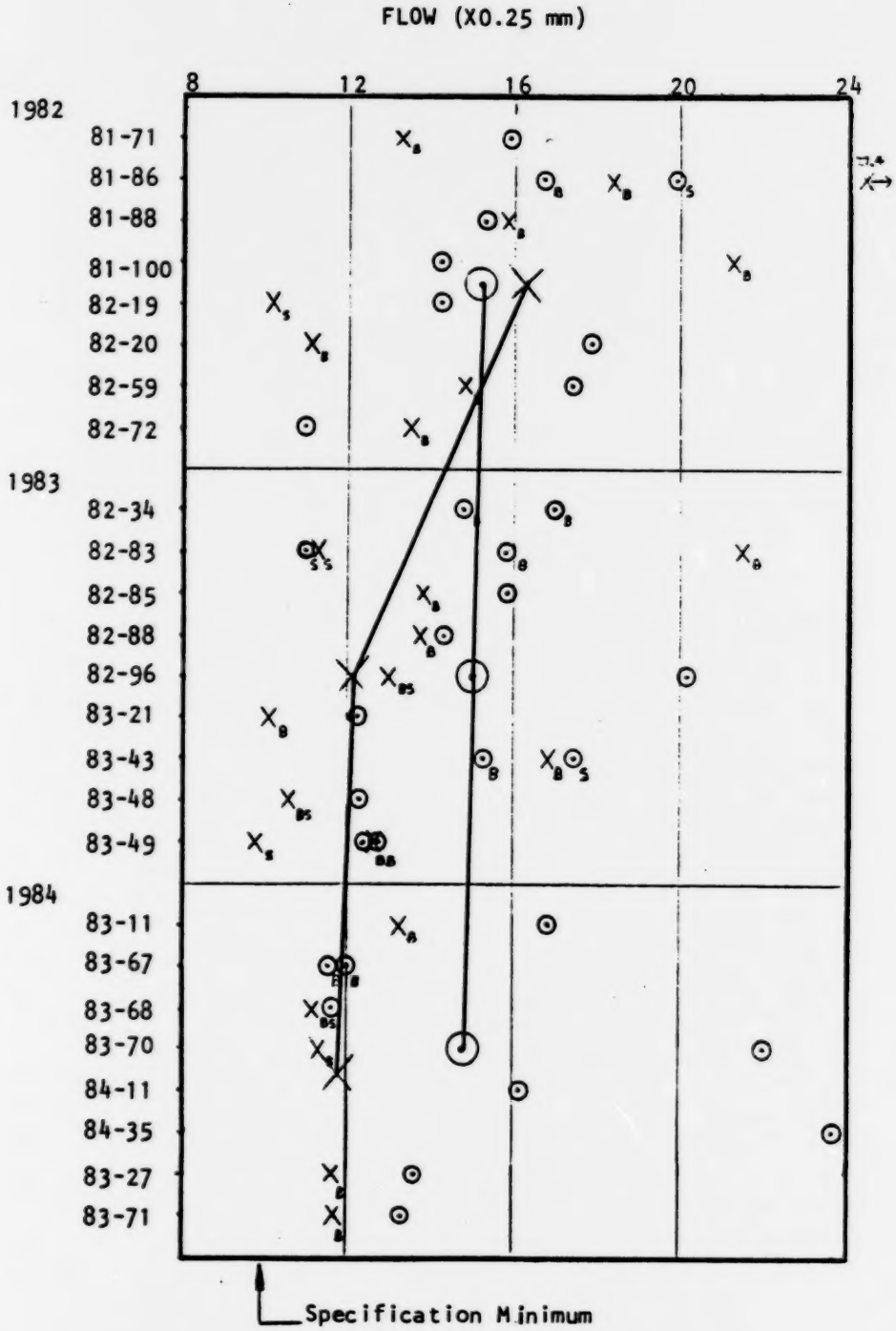



FIG. 11

CENTRAL REGION




X = Mix Design
⊙ = Plant Check
s = Surface Course
B = Binder Course

X—X = Annual Mix Design Average
⊙—⊙ = Annual Plant Check Average

FIG. 12

EASTERN REGION

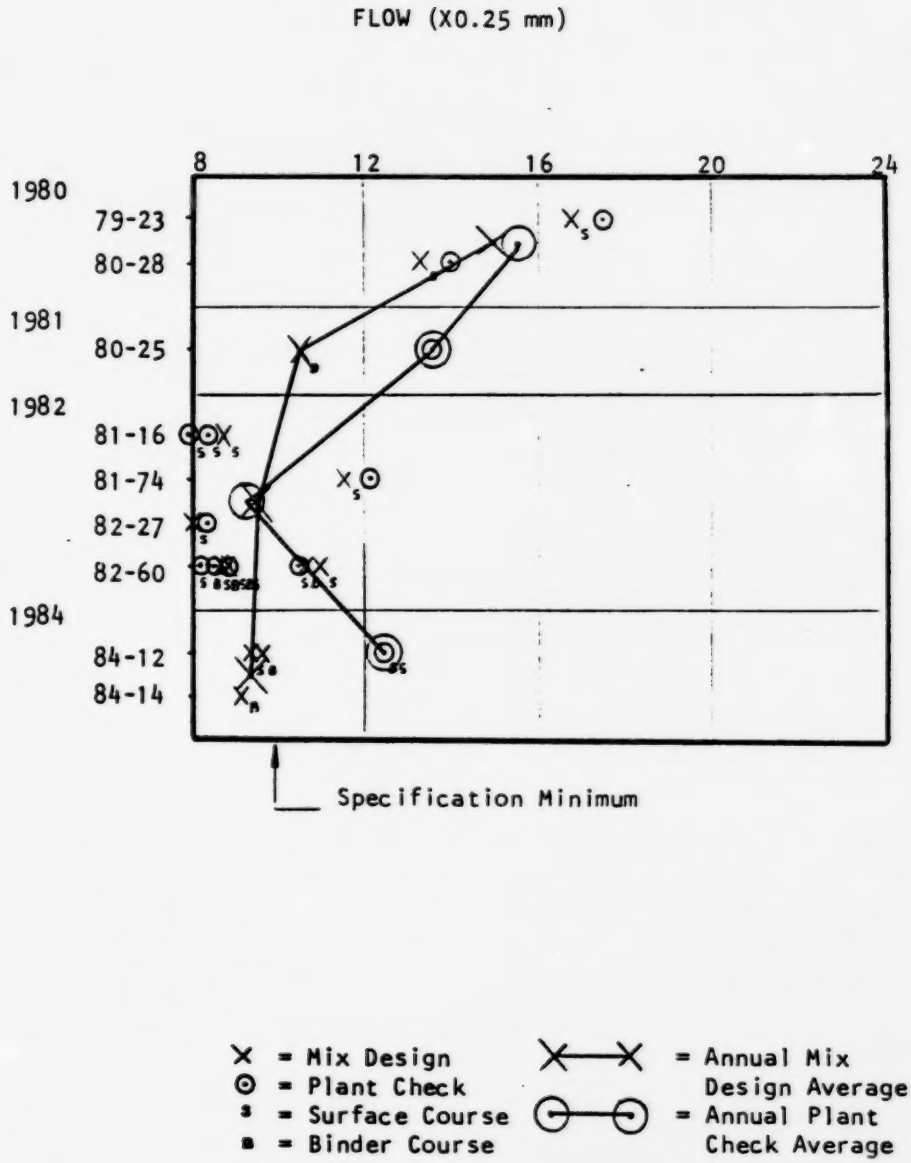
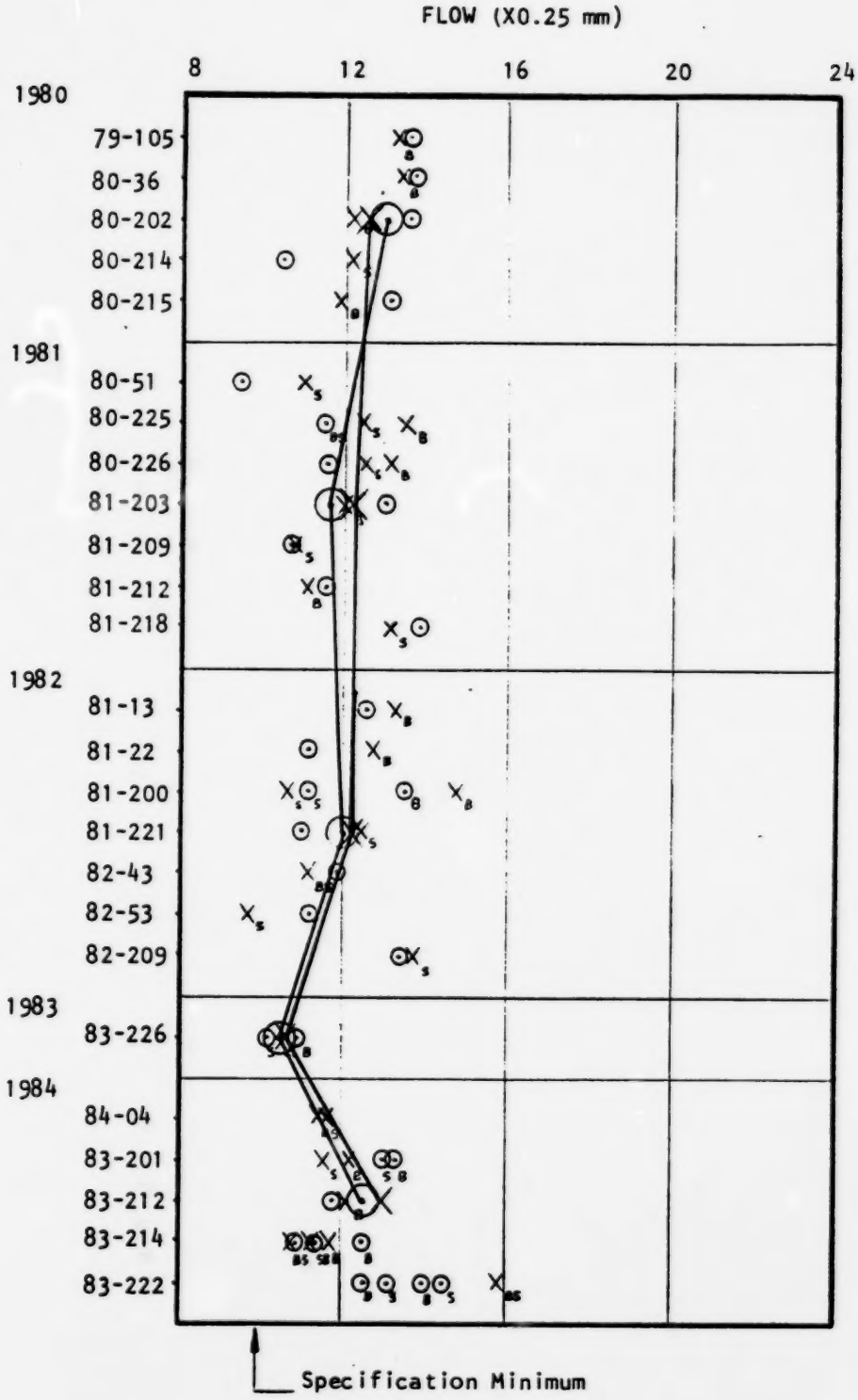



FIG. 13

NORTHERN REGION




X = Mix Design
⊙ = Plant Check
s = Surface Course
B = Binder Course

X——X = Annual Mix Design Average

⊙——⊙ = Annual Plant Check Average

FIG. 14

NORTH-WESTERN REGION

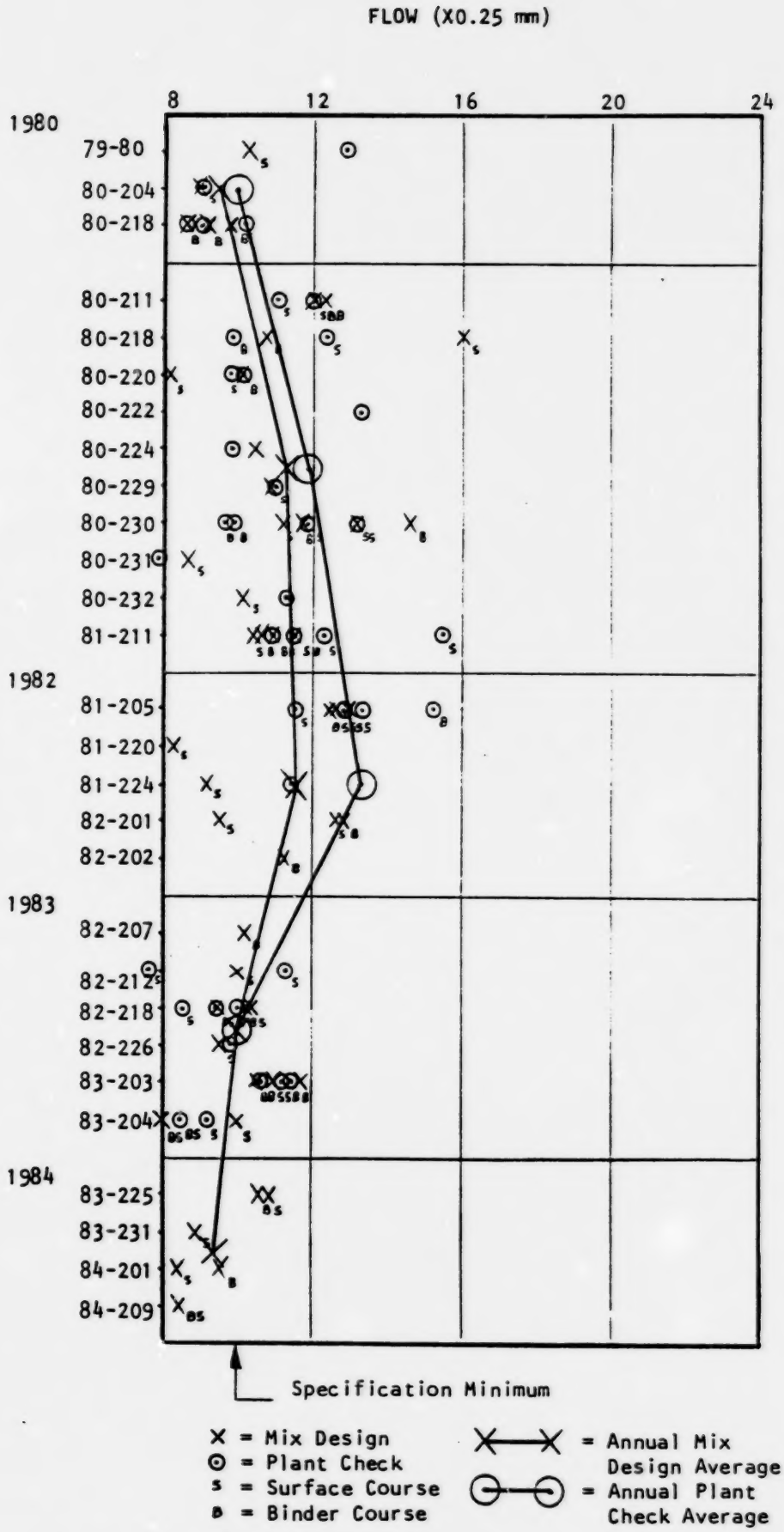



FIG. 15

# TABLE 4

## ANALYSIS OF MARSHALL STABILITY RESULTS

(X 1000N)

| TYPE | LIFT | REGION | AVERAGE | | | | | RANGE | | | | | %IN - SPEC. | | | | | NO. OF MIXES MONITORED | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1980 | 1981 | 1982 | 1983 | 1984 | 1980 | 1981 | 1982 | 1983 | 1984 | 1980 | 1981 | 1982 | 1983 | 1984 | 1980 | 1981 | 1982 | 1983 | 198 |
| MIX DESIGN | Surf. | S.W. | - | - | 12.7 | 12.1 | 10.9 | - | - | 7.8-16.2 | 7.8-17.6 | 8.3-13.3 | - | - | 100 | 100 | 100 | 0 | 0 | 5 | 8 | 11 |
| | | C. | - | - | 11.2 | 15.2 | 13.8 | - | - | 9.8-12.5 | 11.5-20 | 13.8 | - | - | 100 | 100 | 100 | 0 | 0 | 2 | 6 | 1 |
| | | E. | 13.7 | - | 10.2 | - | 10 | 12-15.4 | - | 6.4-13.1 | - | 10 | 100 | - | 100 | - | 100 | 2 | 0 | 6 | 0 | 1 |
| | | N. | 13.1 | 11.6 | 13.6 | 10.1 | 12.8 | 13.1 | 10.6-13.5 | 11.1-20.4 | 10.1 | 10.7-14.6 | 100 | 100 | 100 | 100 | 100 | 1 | 6 | 5 | 1 | 5 |
| | | N.W. | 12.3 | 13.2 | 10.8 | 12.0 | 9.4 | 12.1-12.5 | 8.9-16.5 | 8.3-13.7 | 7.2-15 | 7.3-14.2 | 100 | 100 | 100 | 100 | 100 | 2 | 11 | 6 | 8 | 4 |
| | | PROV. | 13.0 | 12.6 | 11.7 | 12.8 | 11.1 | 12-15.4 | 8.9-16.5 | 6.7-20.4 | 7.2-20 | 7.3-14.6 | 100 | 100 | 100 | 100 | 100 | 5 | 17 | 24 | 23 | 22 |
| | Bind. | S.W. | - | - | 11.5 | 11.8 | 11.0 | - | - | 9.8-12.7 | 7.8-14.1 | 8.3-14.5 | - | - | 100 | 100 | 100 | 0 | 0 | 4 | 5 | 7 |
| | | C. | - | - | 15.3 | 18.6 | 16.7 | - | - | 14.3-16.7 | 12.3-23.5 | 13.8-20.4 | - | - | 100 | 100 | 100 | 0 | 0 | 7 | 7 | 5 |
| | | E. | - | 10.7 | 11.5 | - | 10.7 | - | 10.7 | 8.8-13.2 | - | 9.9-11.4 | - | 100 | 100 | - | 100 | 0 | 1 | 2 | 0 | 2 |
| | | N. | 11.9 | 10.9 | 13.2 | 10.1 | 12.2 | 10.4-12.7 | 10.1-12.2 | 11.5-14.5 | 10.1 | 9.5-14.6 | 100 | 100 | 100 | 100 | 100 | 4 | 3 | 4 | 1 | 7 |
| | | N.W. | 11.2 | 13.4 | 11.5 | 13.4 | 10.7 | 9.5-12.3 | 11.8-16.6 | 11.3-12.4 | 7.2-14.5 | 7.3-17 | 100 | 100 | 100 | 100 | 100 | 3 | 8 | 3 | 6 | 3 |
| | | PROV. | 11.6 | 12.6 | 13.2 | 14.7 | 12.5 | 9.5-12.7 | 10.1-16.6 | 9.8-16.7 | 7.2-23.5 | 7.3-20.4 | 100 | 100 | 100 | 100 | 100 | 7 | 12 | 20 | 19 | 24 |
| PLANT CHECKS | Surf. | S.W. | - | - | 14.6 | 13.9 | 12.1 | - | - | 13.2-16.3 | 10.9-18.8 | 9.4-15.6 | - | - | 100 | 100 | 100 | 0 | 0 | 5 | 10 | 10 |
| | | C. | - | - | 13.1 | 15.4 | 18 | - | - | 12.1-14.1 | 10.7-24 | 17.1-18.9 | - | - | 100 | 100 | 100 | 0 | 0 | 2 | 6 | 2 |
| | | E. | 13.9 | - | 11.1 | - | 11.9 | 13.5-14.3 | - | 8.5-14.4 | - | 11.9 | 100 | - | 100 | - | 100 | 2 | 0 | 7 | 0 | 1 |
| | | N. | 11.7 | 14.4 | 14.5 | 12.0 | 11.1 | 11.7 | 12.3-17.2 | 12.9-16.8 | 12.0 | 12.5-15.1 | 100 | 100 | 100 | 100 | 100 | 1 | 6 | 5 | 1 | 4 |
| | | N.W. | 14.1 | 15.4 | 17.3 | 12.5 | - | 12.3-15.8 | 8.6-18.5 | 16-19.3 | 7.8-15.5 | - | 100 | 100 | 100 | 100 | - | 2 | 12 | 4 | 8 | 0 |
| | | PROV. | 13.5 | 15.1 | 13.9 | 13.7 | 12.5 | 11.7-15.8 | 8.6-18.5 | 8.5-19.3 | 7.8-24 | 9.4-18.9 | 100 | 100 | 100 | 100 | 100 | 5 | 18 | 23 | 25 | 17 |
| | Bind. | S.W. | - | - | 15.0 | 12.6 | 13.3 | - | - | 14.6-16.0 | 11.5-15.6 | 8.2-16.6 | - | - | 100 | 100 | 100 | 0 | 0 | 5 | 5 | 4 |
| | | C. | - | - | 12.6 | 15.7 | 5 | - | - | 11.1-14.4 | 11.4-18.8 | 12.8-17.1 | - | - | 100 | 100 | 100 | 0 | 0 | 7 | 9 | 9 |
| | | E. | - | 13.3 | 10.5 | - | 12.1 | - | 13.3 | 9.3-11.6 | - | 12.1 | - | 100 | 100 | - | 100 | 0 | 1 | 2 | 0 | 1 |
| | | N. | 15.5 | 14.3 | 14.5 | 11.5 | 13.9 | 14.8-17.7 | 12.3-16.1 | 14.3-14.7 | 11.5 | 12-15.5 | 100 | 100 | 100 | 100 | 100 | 4 | 3 | 4 | 1 | 6 |
| | | N.W. | 13.5 | 16.2 | 15.1 | 12.6 | - | 12.4-14.3 | 12.6-18.7 | 15.1 | 7.8-14.7 | - | 100 | 100 | 100 | 100 | - | 3 | 8 | 1 | 6 | 0 |
| | | PROV. | 14.6 | 15.5 | 13.5 | 13.9 | 14.2 | 12.4-17.7 | 12.3-18.7 | 9.3-16 | 7.8-18.8 | 8.2-17.1 | 100 | 100 | 100 | 100 | 100 | 7 | 12 | 19 | 21 | 20 |

SOUTHWESTERN REGION

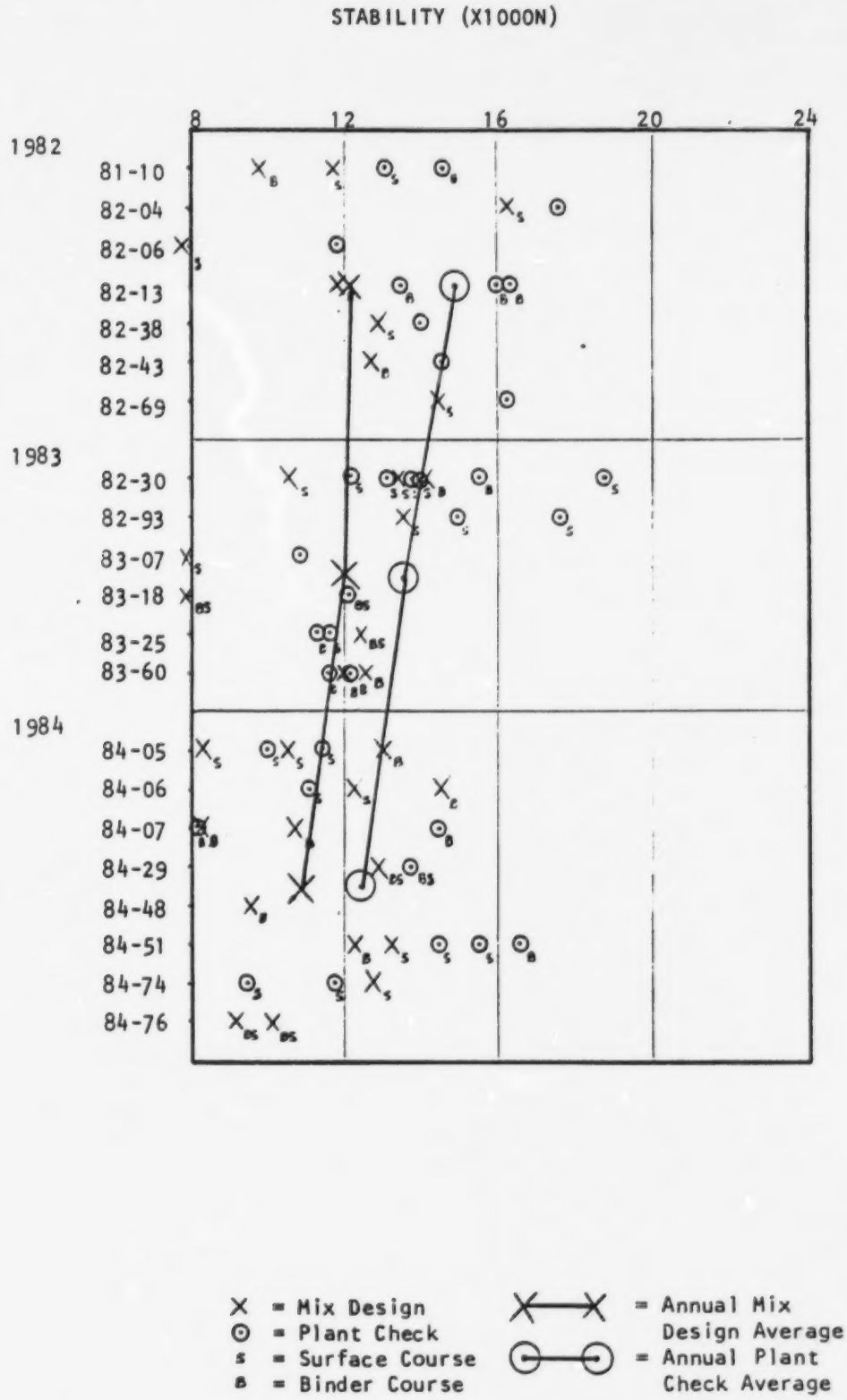



FIG. 16

CENTRAL REGION

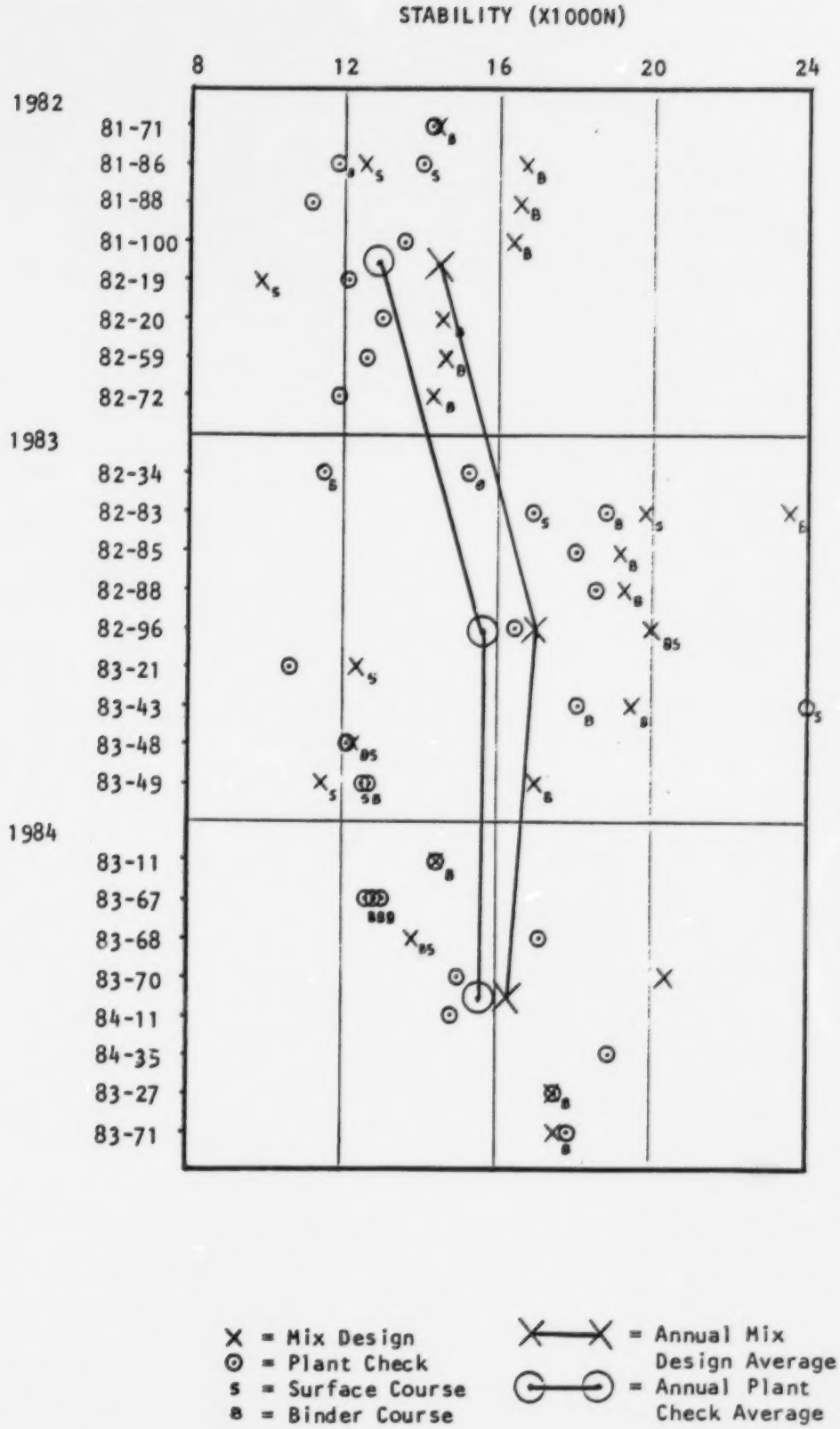
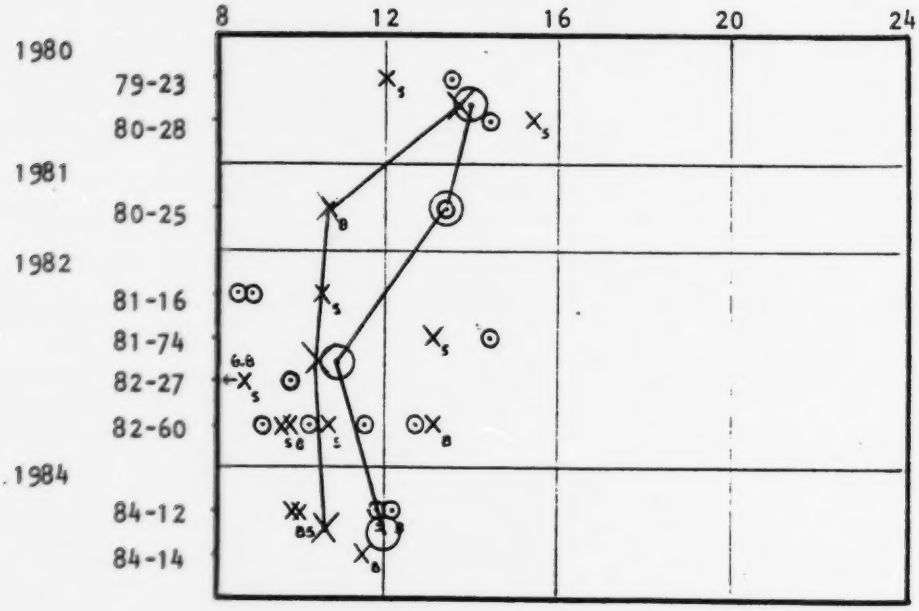



FIG. 17

EASTERN REGION

STABILITY (X1000N)




X = Mix Design
⊙ = Plant Check
s = Surface Course
B = Binder Course

X——X = Annual Mix Design Average

⊙——⊙ = Annual Plant Check Average

FIG. 18

NORTHERN REGION

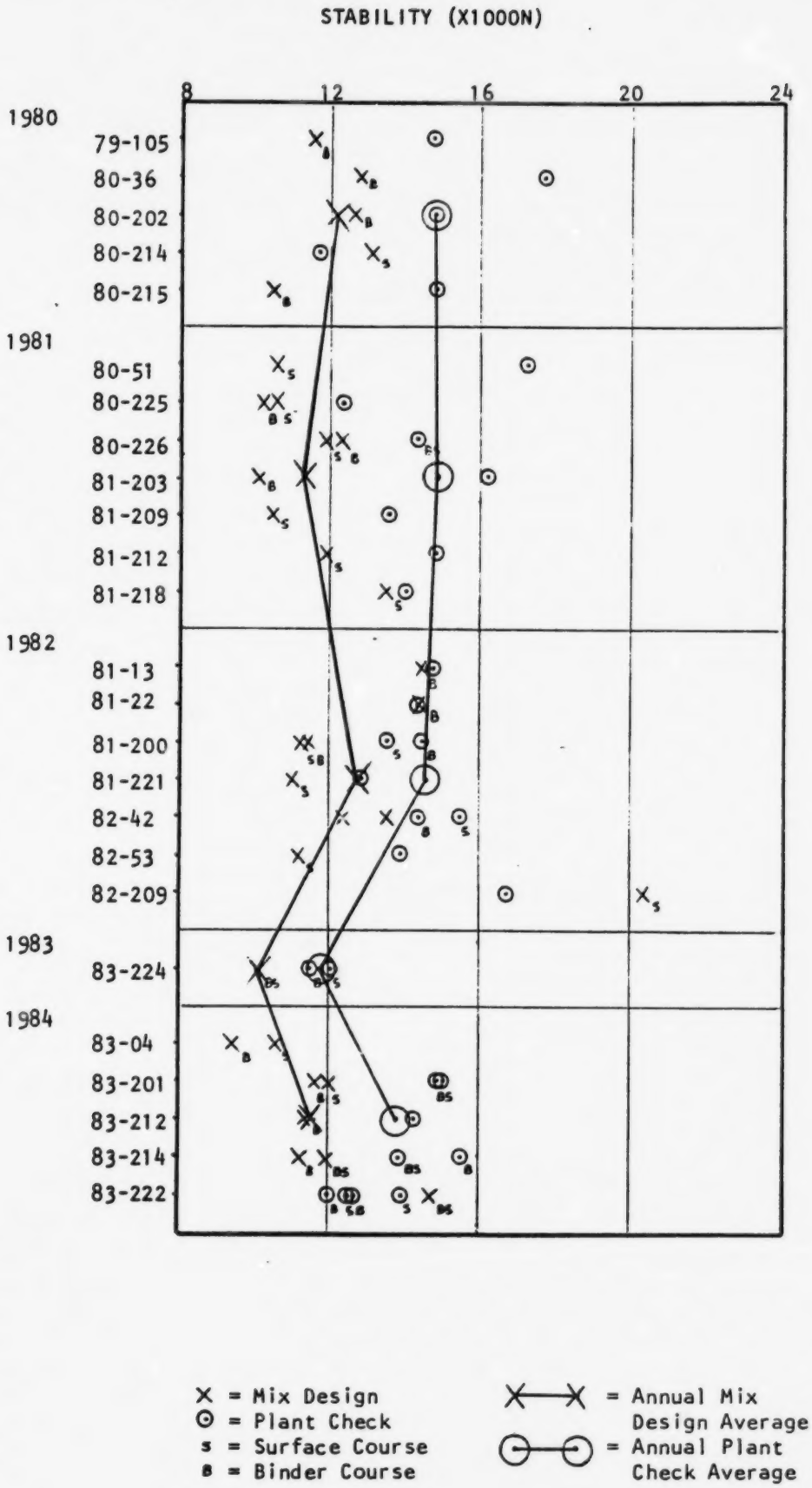



FIG. 19

NORTHWESTERN REGION

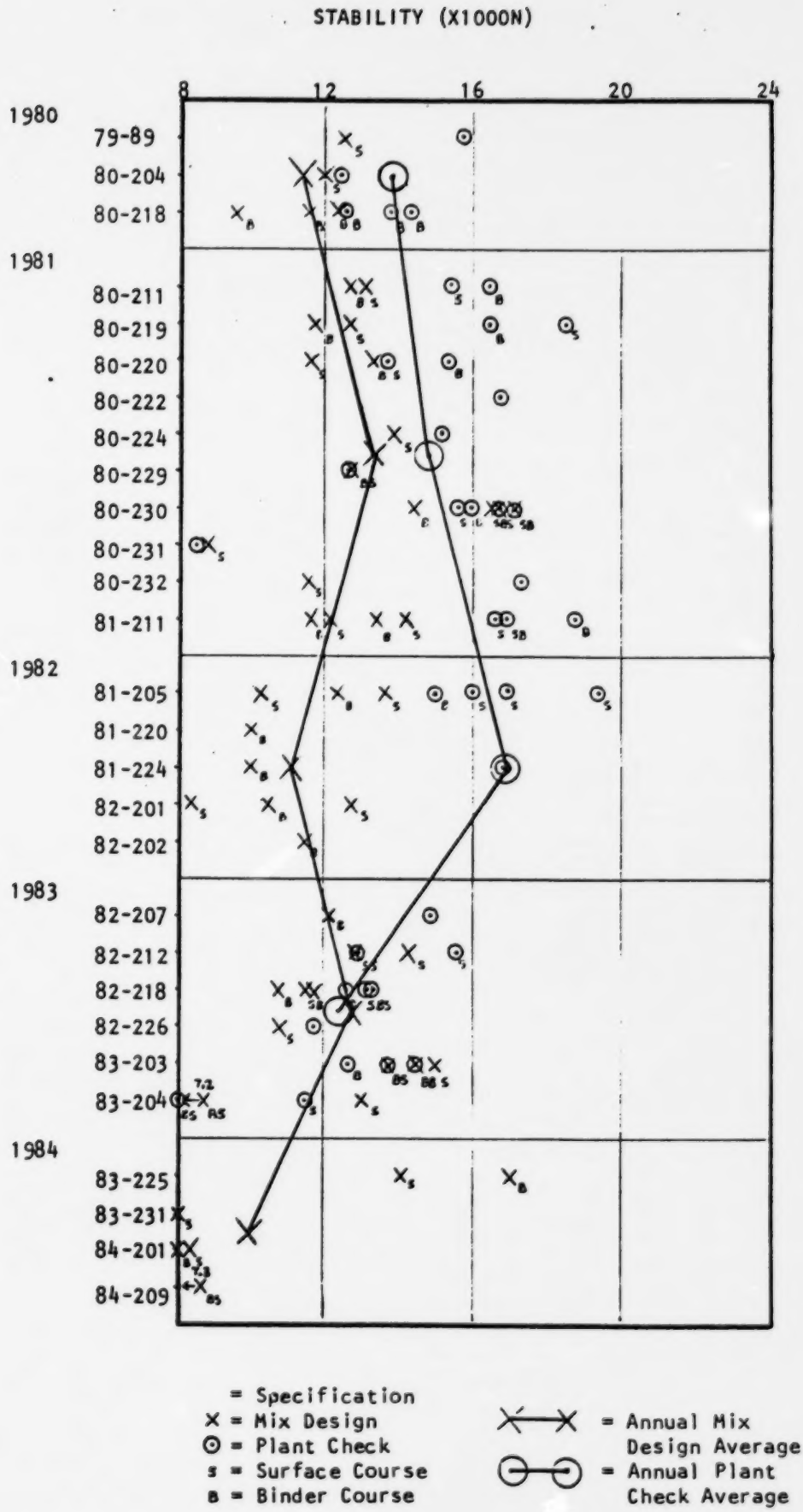


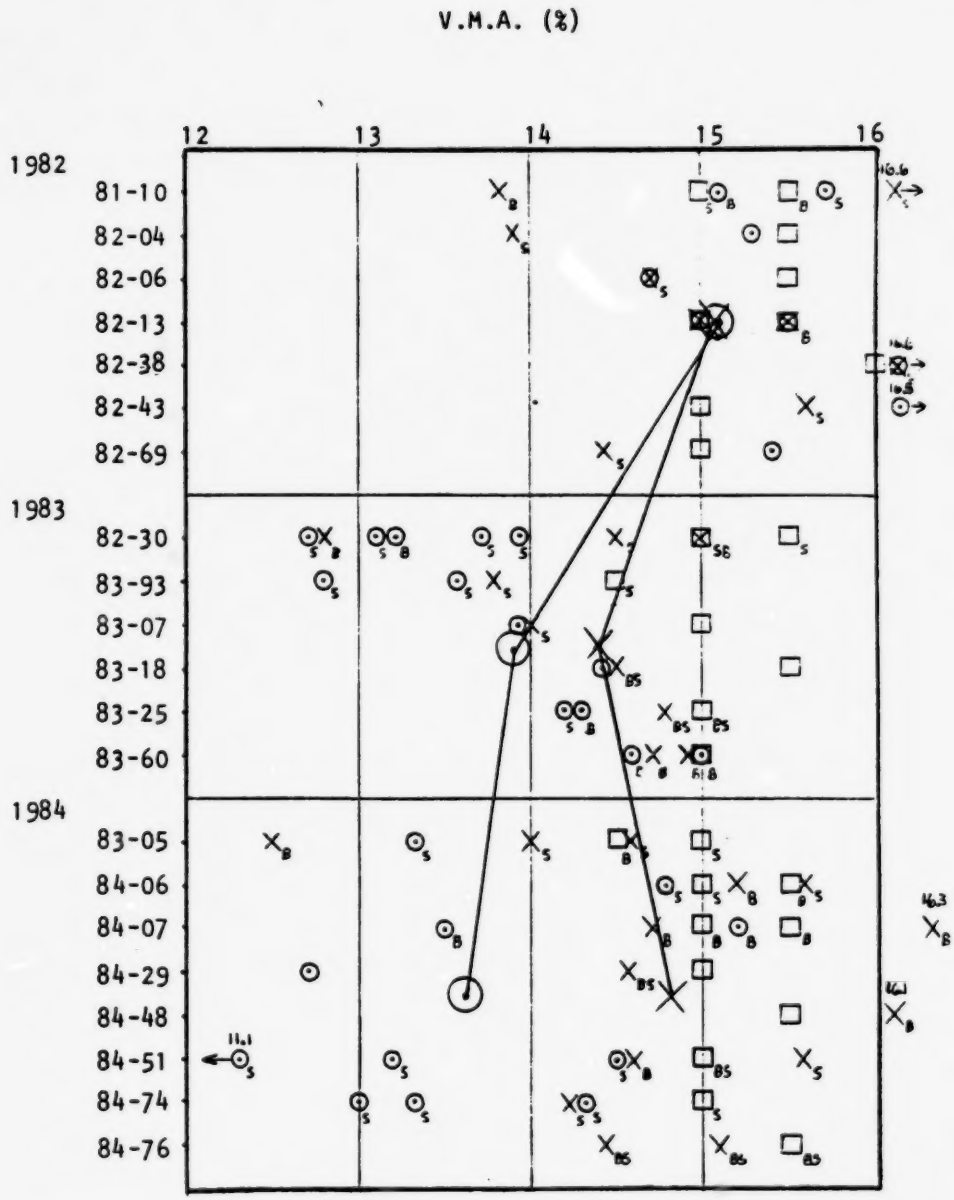

FIG. 20

# TABLE 5

## ANALYSIS OF V.M.A. (%) RESULTS

| TYPE | LIFT | REGION | AVERAGE | | | | | RANGE | | | | | %IN - SPEC. | | | | | NO. OF MIXES MONITORED | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1980 | 1981 | 1982 | 1983 | 1984 | 1980 | 1981 | 1982 | 1983 | 1984 | 1980 | 1981 | 1982 | 1983 | 1984 | 1980 | 1981 | 1982 | 1983 | 1984 |
| MIX DESIGN | Surf. | S.W. | - | - | 15.3 | 14.4 | 14.7 | - | - | 13.9-16.6 | 13.8-15 | 14-15.6 | - | - | 67 | 0 | 30 | 0 | 0 | 6 | 8 | 10 |
| | | C. | - | - | 13.8 | 15 | 13.3 | - | - | 13.8 | 14.3-15.5 | 13.3 | - | - | 0 | 100 | 0 | 0 | 0 | 1 | 5 | 1 |
| | | E. | 12.7 | - | 14.6 | - | 14.9 | 12.7 | - | 13.3-15.1 | - | 14.9 | 0 | - | 67 | - | 0 | 1 | 0 | 6 | 0 | 1 |
| | | N. | - | 13.8 | 14.1 | 14.9 | 14 | - | 12.9-14.9 | 13.3-15.3 | 14.9 | 13.1-14.8 | - | 17 | 20 | 0 | 20 | 0 | 6 | 5 | 1 | 5 |
| | | N.W. | 14.6 | 14.6 | 14.5 | 15.1 | 15.3 | 14.5-14.6 | 14-15.6 | 13.6-15 | 14-15.6 | 15-15.8 | 0 | 9 | 17 | 57 | 100 | 2 | 11 | 6 | 7 | 4 |
| | | PROV. | 14.0 | 14.3 | 14.6 | 14.8 | 14.6 | 12.7-14.6 | 12.9-15.6 | 13.3-16.6 | 13.8-15.6 | 13.1-15.8 | 0 | 12 | 42 | 43 | 38 | 3 | 17 | 24 | 21 | 21 |
| | Bind. | S.W. | - | - | 14.8 | 14.3 | 14.9 | - | - | 13.8-15.5 | 12.8-14.9 | 12.5-16.3 | - | - | 33 | 0 | 29 | 0 | 0 | 3 | 5 | 7 |
| | | C. | - | - | 12.9 | 13.8 | 14.3 | - | - | 12.5-13.5 | 12.1-15.1 | 13.3-16.3 | - | - | 0 | 29 | 40 | 0 | 0 | 6 | 7 | 5 |
| | | E. | - | 14 | 14.5 | - | 14.9 | - | 14 | 14.8-13.2 | - | 14.9 | - | 0 | 50 | - | 0 | 0 | 1 | 2 | 0 | 2 |
| | | N. | - | 14.3 | 14 | 14.9 | 13.3 | - | 13.6-14.9 | 13.4-14.7 | 14.9 | 13.3-15.6 | - | 0 | 0 | 0 | 29 | 0 | 3 | 4 | 1 | 7 |
| | | N.W. | 14.7 | 14.3 | 14.1 | 15 | 15.4 | 14.4-15.1 | 13.5-14.9 | 13.5-14.7 | 14.1-15.6 | 15-15.6 | 0 | 0 | 0 | 67 | 100 | 3 | 8 | 3 | 6 | 3 |
| | | PROV. | 14.7 | 14.3 | 13.8 | 14.4 | 14.4 | 14.4-15.1 | 13.5-14.9 | 12.5-15.5 | 12.1-15.6 | 12.5-16.3 | 0 | 0 | 11 | 32 | 38 | 3 | 12 | 18 | 19 | 24 |
| PLANT CHECKS | Surf. | S.W. | - | - | 15.7 | 13.6 | 13.3 | - | - | 15.3-16.6 | 12.7-14.4 | 11.1-14.8 | - | - | 67 | 0 | 0 | 0 | 0 | 6 | 10 | 10 |
| | | C. | - | - | 16.3 | 13.6 | 11.5 | - | - | 14.3-18.2 | 9.5-16.3 | 9.4-13.5 | - | - | 100 | 50 | 0 | 0 | 0 | 2 | 6 | 2 |
| | | E. | 14.2 | - | 15.2 | - | 13.7 | 14.1-14.3 | - | 14.8-15.5 | - | 13.7 | 0 | - | 86 | - | 0 | 2 | 0 | 7 | 0 | 1 |
| | | N. | 15.6 | 15.4 | 15.4 | 14.3 | 13.3 | 15.6 | 14.2-16.9 | 14.3-16.5 | 14.3 | 12.7-13.9 | 100 | 86 | 75 | 0 | 0 | 1 | 6 | 4 | 1 | 4 |
| | | N.W. | 15.1 | 13.8 | 14.1 | 14.9 | 14.9 | 14.5-15.6 | 12.7-14.9 | 13.8-14.7 | 13.9-16 | 13.9-15.5 | 50 | 0 | 0 | 63 | 75 | 2 | 12 | 7 | 8 | 4 |
| | | PROV. | 14.8 | 14.3 | 15.1 | 14.0 | 13.5 | 14.1-15.6 | 12.7-16.9 | 13.8-18.2 | 9.5-16.3 | 9.4-15. | 40 | 28 | 58 | 32 | 14 | 5 | 18 | 26 | 25 | 21 |
| | Bind. | S.W. | - | - | 15.2 | 14.3 | 14.0 | - | - | 15-15.5 | 14.3-15 | 12.7-15.2 | - | - | 25 | 20 | 0 | 0 | 0 | 4 | 5 | 4 |
| | | C. | - | - | 14.5 | 14 | 13.6 | - | - | 13.8-15.4 | 11.8-17.4 | 12-15.9 | - | - | 57 | 38 | 11 | 0 | 0 | 7 | 8 | 9 |
| | | E. | - | 15.4 | 15.2 | - | 13.7 | - | 15.4 | 15.1-15.3 | - | 13.7 | - | 100 | 100 | - | 0 | 0 | 1 | 2 | 0 | 1 |
| | | N. | 15.2 | 15.6 | 15.1 | 14.8 | 13.8 | 14.9-15.4 | 14.2-16.9 | 14.2-15.9 | 14.8 | 12.9-14.8 | 50 | 67 | 75 | 100 | 17 | 4 | 3 | 4 | 1 | 6 |
| | | N.W. | 15.8 | 13.9 | 14.2 | 14.9 | 14.5 | 14.9-17.2 | 12.9-15 | 13-15.7 | 13.9-15.7 | 14-14.9 | 67 | 13 | 33 | 50 | 0 | 3 | 8 | 3 | 6 | 3 |
| | | PROV. | 15.5 | 14.5 | 14.8 | 14.4 | 13.8 | 14.9-17.2 | 12.5-16.9 | 13-15.9 | 11.8-17.4 | 12-15.9 | 57 | 25 | 55 | 40 | 9 | 7 | 12 | 20 | 20 | 23 |

SOUTHWESTERN REGION




□ = Specification

X = Mix Design

⊙ = Plant Check

s = Surface Course

B = Binder Course

X—X = Annual Mix Design Average

⊙—⊙ = Annual Plant Check Average

FIG. 21

CENTRAL REGION

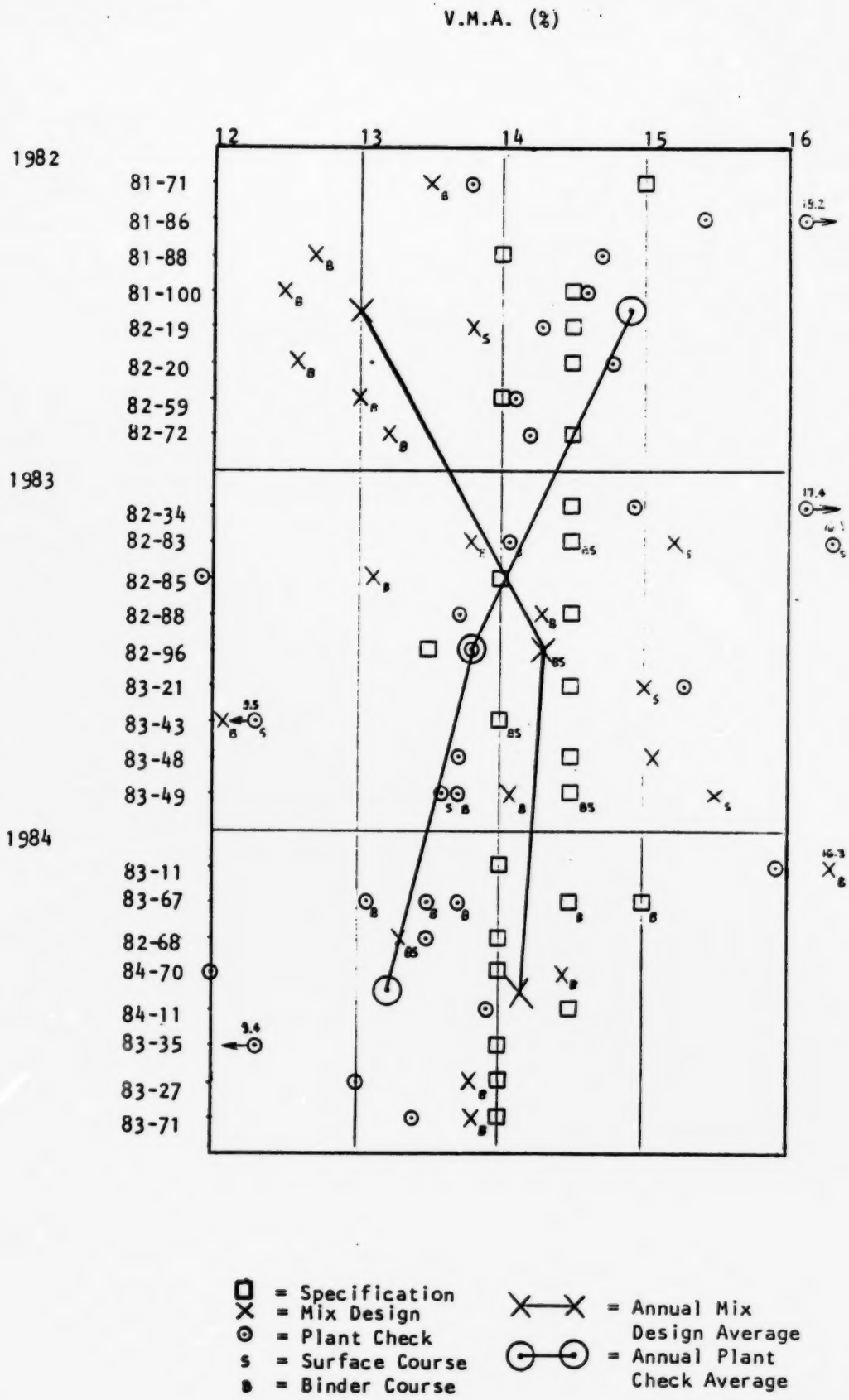



FIG. 22

EASTERN REGION

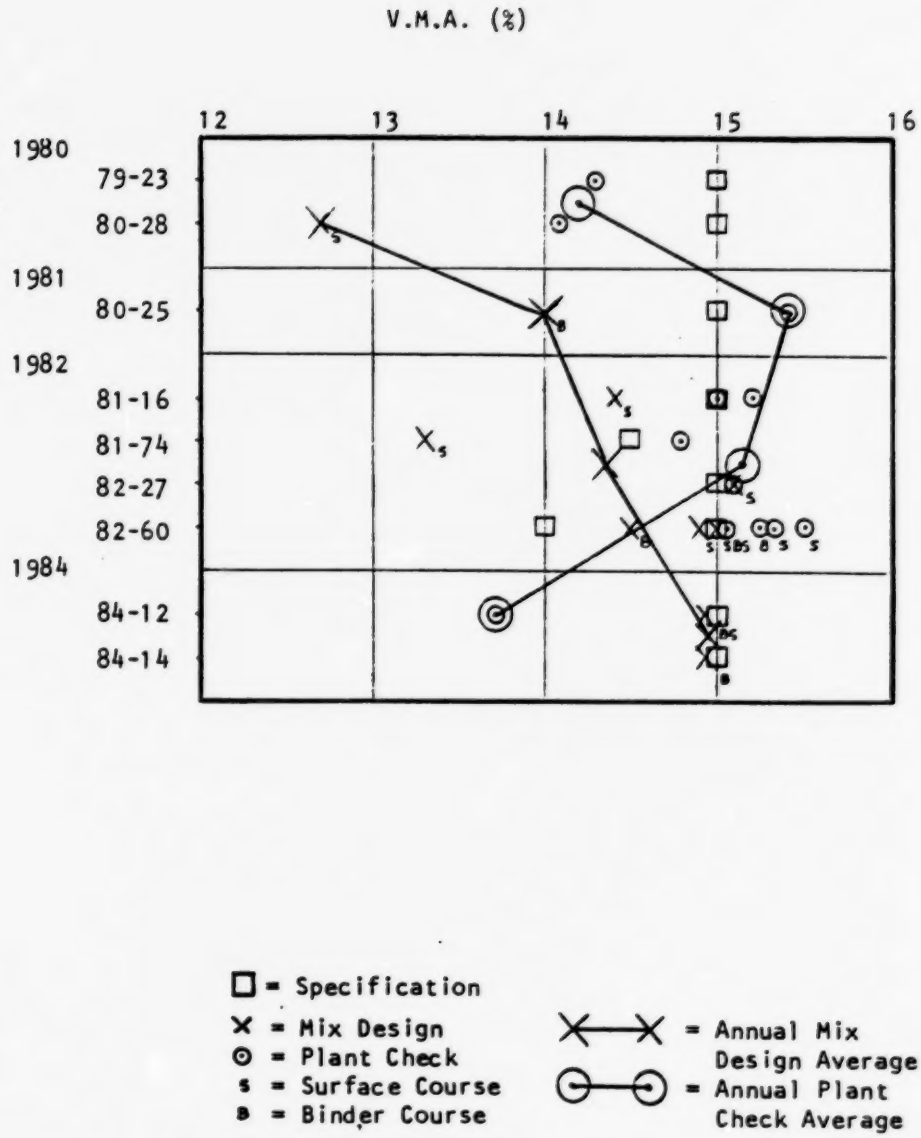
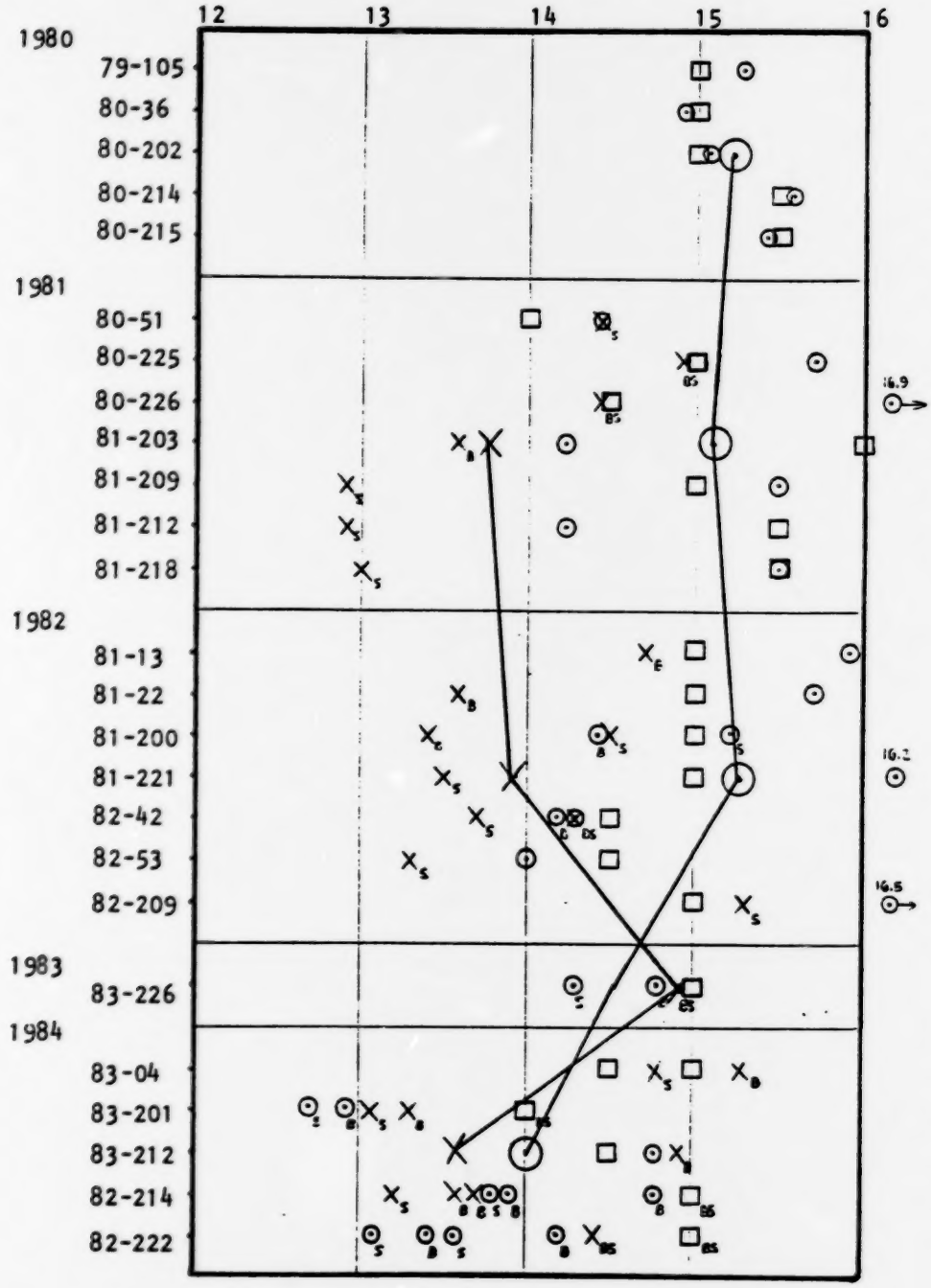



FIG. 23

NORTHERN REGION

V.M.A. (%)



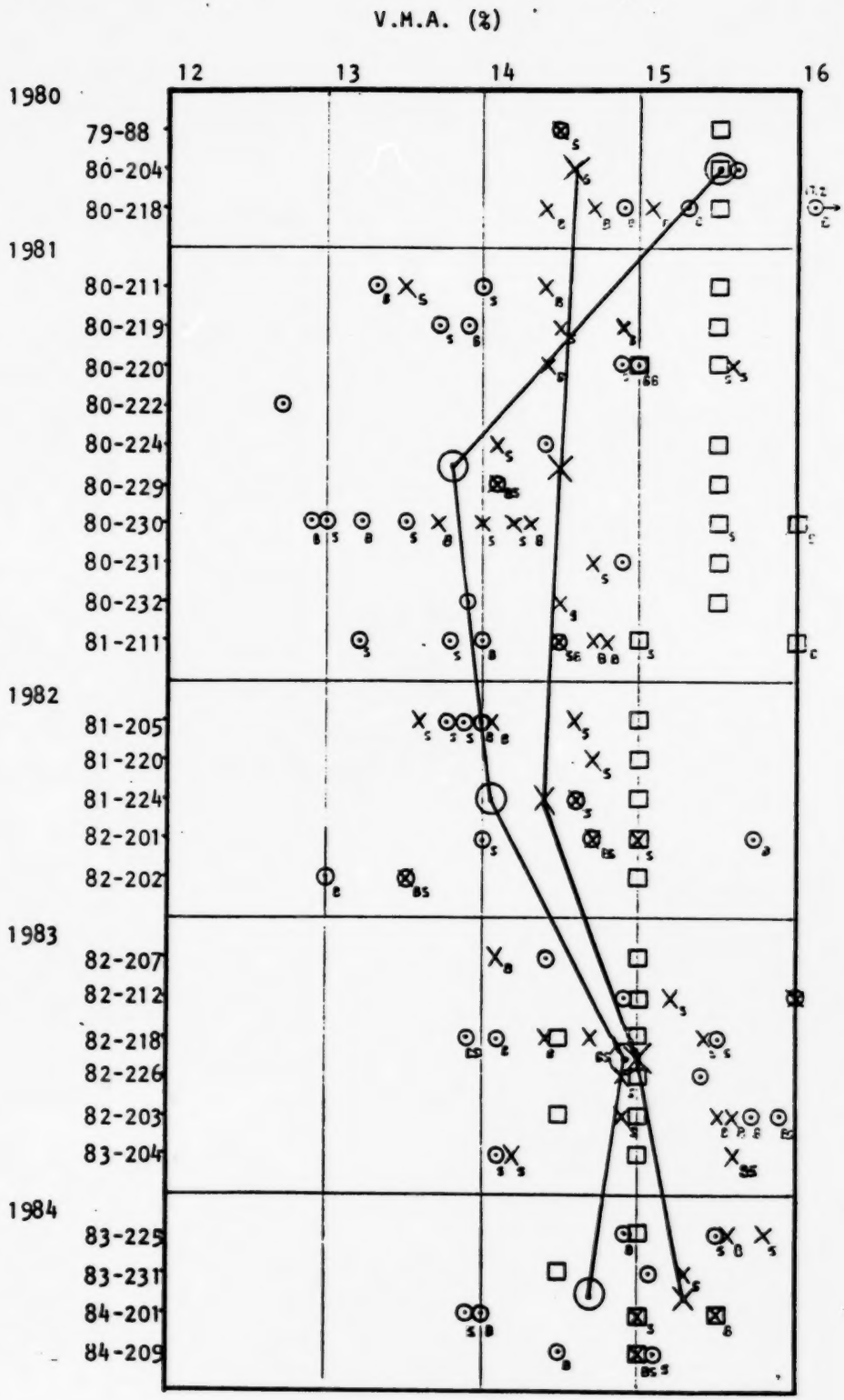

□ = Specification
× = Mix Design
⊙ = Plant Check
s = Surface Course
B = Binder Course

= Annual Mix Design Average


= Annual Plant Check Average

FIG. 24

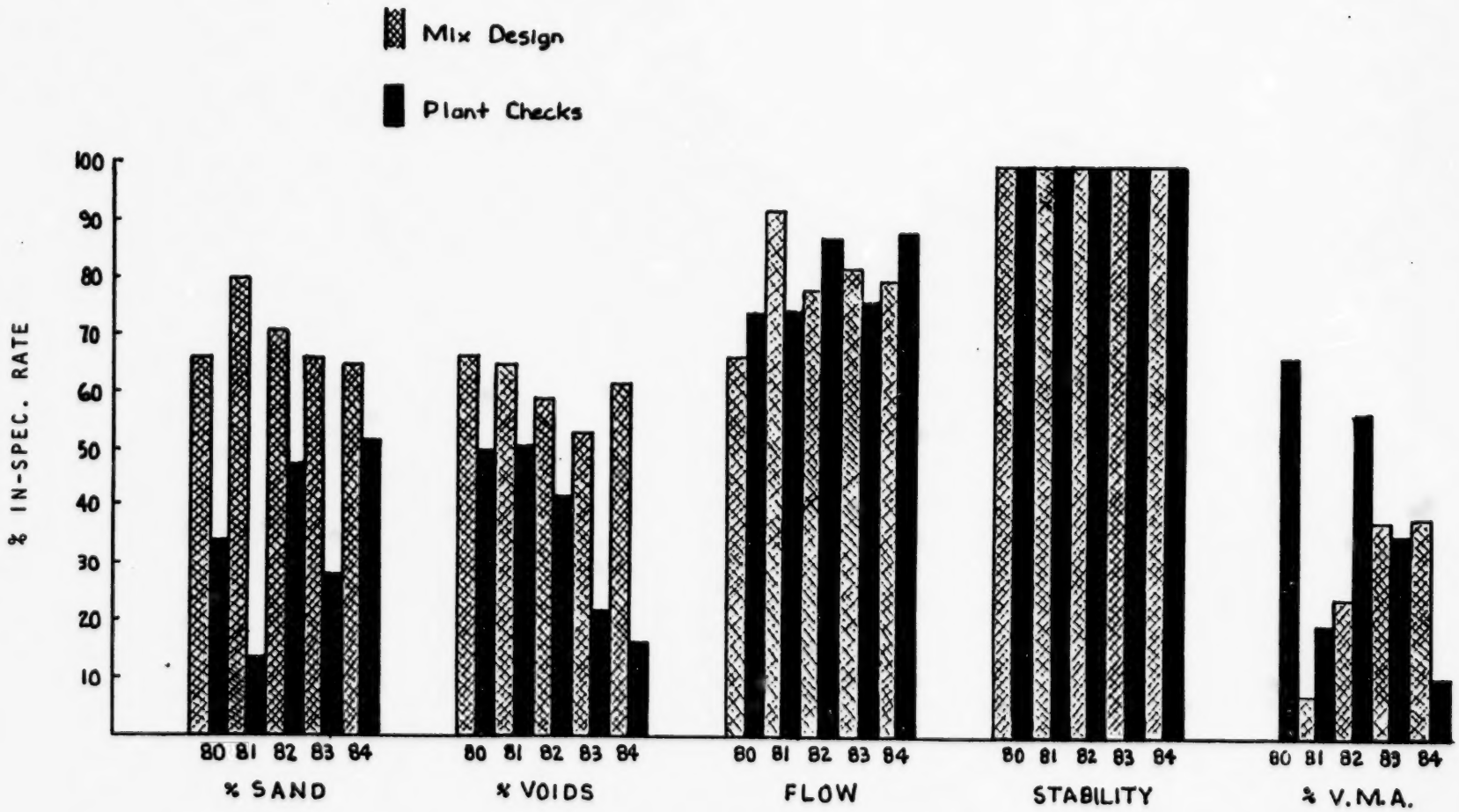
NORTHWESTERN REGION




□ = Specification
X = Mix Design
⊙ = Plant Check
S = Surface Course
B = Binder Course

X—X = Annual Mix Design Average
⊙—⊙ = Annual Plant Check Average

FIG. 25




PERCENTAGE OF MIXES MEETING DIFFERENT PROPERTY REQUIREMENTS

FIG. 26

TABLE 6: A.C. Penetration of Recycled Hot Mixes

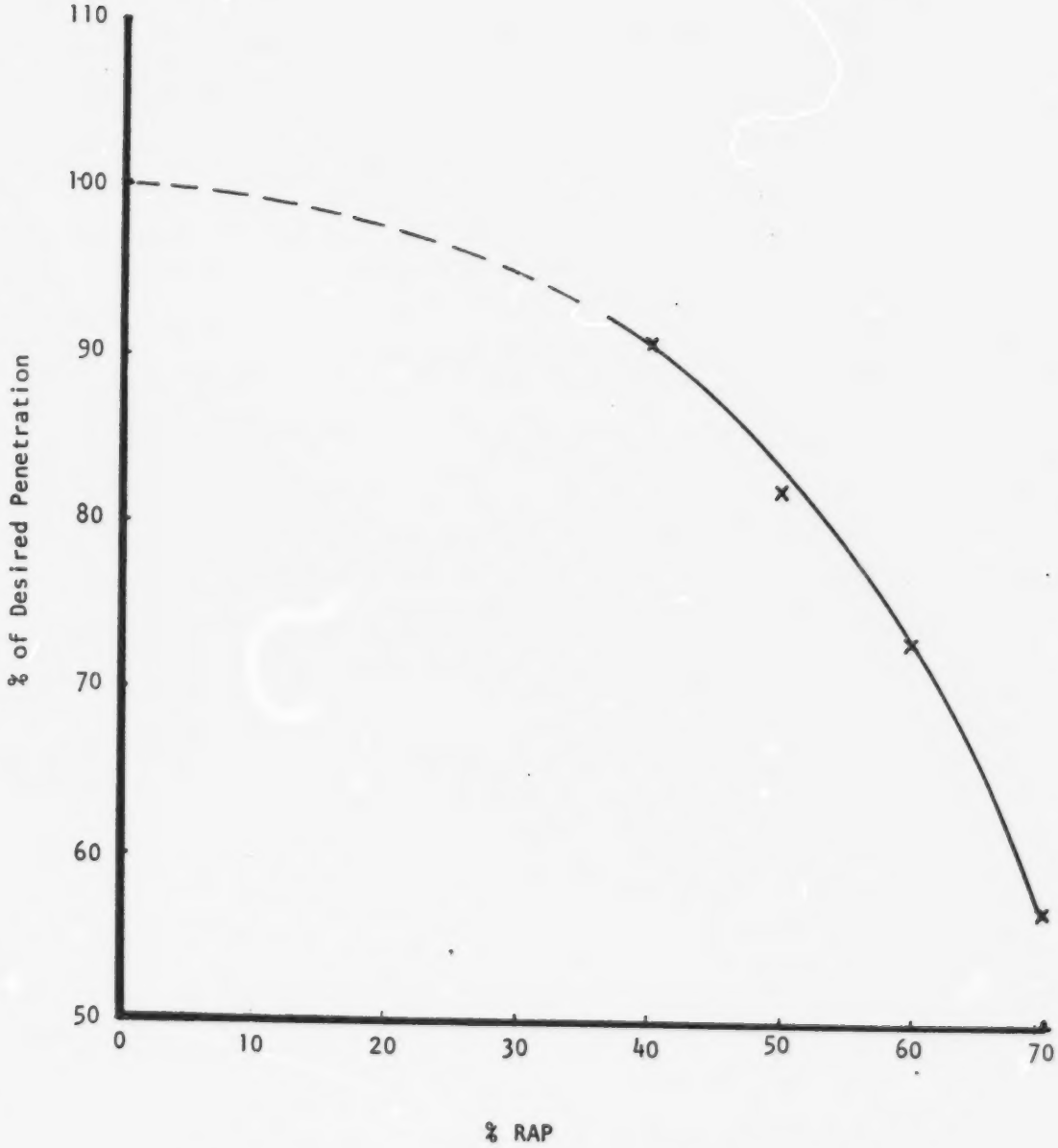
| Cons. Year | Contract | A.C. Grade for Virgin Resurfacing Mix | # of "Grade Softer" | Pen. of Recycled Mix (a) | Desired Pen. (b) | % of Desired Pen. ($^a/_b$ x100) |
|---|---|---|---|---|---|---|
| 1981 | 80-220 | 150/200 | 1 | 91 | 100 | 91 |
| | 80-222 | 150/200 | 1 | 49 | 100 | 49 |
| | 80-210 | 150/200 | 1 | 49 | 100 | 49 |
| | 80-211 | 150/200 | 1 | 68 | 100 | 68 |
| | 80-025 | 85/100 | 1 | 32 | 60 | 53 |
| | 81-211 | 150/200 | 1 | 61 | 100 | 61 |
| | 80-225 | 150/200 | 1 | 68 | 100 | 68 |
| | 80-226 | 150/200 | 1 | 46 | 100 | 46 |
| | 81-209 | 150/200 | 1 | 53 | 100 | 53 |
| | 81-218 | 150/200 | 1 | 67 | 100 | 67 |
| | 81-212 | 150/200 | 1 | 75 | 100 | 75 |
| | 80-202 | 150/200 | 1 | 39 | 100 | 39 |
| | 81-203 | 150/200 | 1 | 55 | 100 | 55 |
| | 80-036 | 150/200 | 0 | 57 | 100 | 57 |
| | 80-028 | 85/100 | 0 | 46 | 60 | 77 |
| | 80-229 | 150/200 | 1 | 53 | 100 | 53 |
| | 80-230 | 150/200 | 1 | 61 | 100 | 61 |
| 1982 | 82-013 | 150/200 | 1 | 75 | 100 | 75 |
| | 81-016 | 150/200 | 2 | 82 | 100 | 82 |
| | 81-074 | 85/100 | 2 | 58 | 60 | 97 |
| | 81-027 | 150/200 | 2 | 91 | 100 | 91 |
| | 82-060 | 150/200 | 2 | 84 | 100 | 84 |
| 1983 | 82-093 | 85/100 | 1 | 27 | 60 | 45 |
| | 83-007 | 85/100 | 3 | 68 | 60 | 113 |
| | 83-018 | 85/100 | 2 | 58 | 60 | 97 |
| | 83-025 | 85/100 | 2 | 54 | 60 | 90 |
| | 83-060 | 85/100 | 1 | 44 | 60 | 73 |
| | 82-207 | 85/100 | 1. | 59 | 60 | 98 |
| | 82-212 | 150/200 | 1 | 107 | 100 | 107 |
| | 82-218 | 150/200 | 1 | 75 | 100 | 75 |
| | 82-226 | 150/200 | 1 | 79 | 100 | 79 |
| | 82-203 | 85/100 | 1 | 68 | 60 | 113 |
| | 83-204 | 150/200 | 1 | 141 | 100 | 141 |
| 1984 | 84-074 | 85/100 | 2 | 43 | 60 | 72 |
| | 83-214 | 85/100 | 2 | 62 | 60 | 103 |
| | 83-225 | 85/100 | 1 | 68 | 60 | 113 |
| | 83-231 | 150/200 | 1 | 113 | 100 | 113 |
| | 84-201 | 85/100 | 1 | 71 | 60 | 118 |
| | 84-209 | 150/200 | 1 | 109 | 100 | 109 |

# TABLE 7

## ASPHALT CEMENT PENETRATION PREDICTION VALUES FOR R.H.M.

| Contract | Recyc. Ratio | % A.C. of RHM | RAP A.C. | | Virgin A.C. | | Recorded A.C. Pen. of R.H.M. | Pred. Can | Pred. Pen. (Pp) |
|---|---|---|---|---|---|---|---|---|---|
| | | | Pen. (Po) | % RHM (x) | Pen. (Pn) | % RHM (y) | | | |
| 82-13 | 45:55 | 5.2 | 38 | 1.6 | 163 | 3.6 | 75 | .55 | 62 |
| 82-93 | 70:30 | 5.3 | 23 | 4.2 | 120 | 1.1 | 27 | .34 | 20 |
| 83-07 | 50:50 | 5.1 | 38 | 2.5 | 505 | 2.6 | 68 | .52 | 89 |
| 83-18 | 50:50 | 5.6 | 24 | 2.8 | 303 | 2.8 | 58 | .52 | 52 |
| 83-25 | 40:60 | 5.2 | 20 | 1.9 | 304 | 3.3 | 54 | .54 | 67 |
| 83-60 | 45:55 | 5.1 | 27 | 2.1 | 148 | 3.0 | 44 | .54 | 45 |
| 84-74 | 50:50 | 5.5 | 25 | 3.0 | 381 | 2.5 | 43 | .51 | 53 |
| 81-16 | 30:70 | 5.6 | 35 | 1.5 | 369 | 4.1 | 82 | .55 | 116 |
| 81-74 | 50:50 | 5.3 | 31 | 2.6 | 372 | 2.7 | 58 | .53 | 68 |
| 82-60 | 70:30 | 5.4 | 39 | 2.8 | 490 | 2.6 | 84 | .52 | 81 |
| 83-214 | 70:30 | 5.1 | 41 | 3.1 | 338 | 2.0 | 62 | .48 | 58 |
| | 60:40 | 5.0 | 41 | 3.2 | 338 | 2.2 | 57 | .46 | 80 |
| 82-27 | 40:60 | 5.6 | 23 | 1.7 | 460 | 3.9 | 91 | .54 | 109 |
| 82-207 | 50:50 | 5.3 | 52 | 2.2 | 168 | 3.1 | 59 | .54 | 63 |
| 82-212 | 50:50 | 5.3 | 42 | 2.0 | 319 | 3.3 | 107 | .54 | 89 |
| 82-218 | 65:35 | 5.3 | 39 | 2.5 | 330 | 2.8 | 75 | .53 | 74 |
| 82-226 | 40:60 | 5.5 | 30 | 1.9 | 323 | 3.6 | 79 | .55 | 86 |
| 83-203 | 50:50 | 5.4 | 33 | 2.6 | 165 | 2.8 | 68 | .52 | 46 |
| | 50:50 | 5.4 | 45 | 2.2 | 165 | 3.2 | 68 | .54 | 59 |
| | 30:70 | 5.3 | 33 | 1.3 | 165 | 4.0 | 62 | .55 | 65 |
| 83-204 | 17:83 | 5.2 | 46 | 0.8 | 320 | 4.4 | 141 | .55 | 136 |
| 83-225 | 60:40 | 5.3 | 38 | 2.3 | 165 | 3.0 | 47 | .54 | 53 |
| | 35:65 | 5.5 | 31 | 0.8 | 165 | 4.7 | 68 | .55 | 74 |
| 83-231 | 30:70 | 5.5 | 27 | 0.8 | 326 | 4.7 | 113 | .55 | 130 |
| 84-201 | 40:60 | 5.3 | 29 | 2.3 | 187 | 3.0 | 60 | .54 | 51 |
| | 25:75 | 5.5 | 32 | 1.4 | 187 | 4.1 | 71 | .55 | 70 |
| 84:209 | 30:70 | 5.3 | 46 | 1.8 | 328 | 3.5 | 109 | .55 | 101 |

Fig. 27: Influence of % RAP on the Achievable Level of Desired Penetration



# APPENDIX 1

## GENERAL CONTRACT INFORMATION

REGION: SOUTHWESTERN

| YEAR | CONTRACT | HWY | LOCATION | A.A.D.T. | QUANTITY | CONT. DESIGN RATIO | Mix DESIGN RATIO | VIRGIN AGG. Used |
|---|---|---|---|---|---|---|---|---|
| 1982 | 82-13 | 7 | Kitchener | 17500 | 11500<br>HL-4R | 40:60 | 40:60<br>50:60<br>45:55 | BL.<br>ST., SA. |
| 1983 | 82-30 | 86<br>23 | Heron County | 3200 | 55214<br>HL-4R | 70:30<br>40:60 | 70:30<br>60:40<br>50:50 | BL.<br>ST., SA. |
| | 82-93 | 21 | Grand Bend | 3850 | 14977<br>HL-4R | 70:30 | 70:30 | BL.<br>ST., SA. |
| | 83-07 | 2 | Thamesville | 4000 | 15062 | 35:65 | 50:50 | BL.<br>ST., SA. |
| | 83-18 | 7<br>22 | Lambton | 1800 | 16187<br>HL-4R | 30:70 | 50:50 | BL.<br>ST., SA. |
| | 83-25 | 11<br>88 | Bradford | 5400 | 11245<br>HL-3R | 40:60 | 40:60 | BL.<br>ST., SA. |
| | 83-60 | 7<br>8 | Stratford | 6200 | 10055<br>HL-4R | 54:46 | 45:55 | BL.<br>ST., SA. |
| 1984 | 84-05 | 7 | Ailsa Graig | 1800 | 20254<br>HL-4R | 70:30 | 50:50 | BL.<br>ST., SA. |
| | 84-06 | 59 | Port Rowan | 2000 | 18594<br>HL-4R | 70:30 | 50:50<br>0: 0 | BL.<br>ST., SA. |
| | 84-07 | 12 | Atherley | 10800 | 10237<br>HL-4R | 50:50 | 40:60<br>50:50 | BL.<br>ST., SA. |
| | 84-29 | 4 | Blyth | 2250 | 14933<br>HL-4R | 50:50 | 50:50 | BL.<br>ST., SA. |
| | 84-48 | 7<br>8 | Shakespeare | 7000 | 7374<br>HL-4R | 48:52 | 50:50 | BL.<br>ST., SA. |
| | 84-51 | 10 | Caledon | 3000 | 9684<br>HL-4R | 50:50 | 50:50 | SL., SCR |
| | | | | | 9694 | 25:75 | 25:75 | BL.<br>ST., SA. |
| | 84-74 | 7 | Lambton | 1800 | 34594<br>HL-4R | 50:50 | 50:50<br>40:60<br>35:65<br>30:70 | BL.<br>ST., SA. |
| | 84-76 | 9 | Orangeville | 5000 | 18445<br>HL-3R | 50:50 | 45:45 | BL.<br>ST., SA. |

REGION: CENTRAL

| YEAR | CONTRACT | HWY | LOCATION | A.A.D.T. | QUANTITY | CONT. DESIGN RATIO | Mix DESIGN RATIO | VIRGIN AGG. Used |
|---|---|---|---|---|---|---|---|---|
| 1982 | 82-72 | 401 | Whitbyner | 60000 | 17500<br>HL-8R | 40:60 | 40:60<br>50:60 | SA.& GR.<br>BL. SA. |
| 1983 | 82-34 | 26 | Milton | 6000 | 23128<br>HL-4R | 40:60 | 40:60 | BL.<br>ST., SA.<br>SCR. |
| | 82-85 | QEW | Burlington | 57300 | 33921<br>HL-8R | 40:60 | 40:60 | BL.<br>ST., SA. |
| | 82-88 | 55 | Niagara | 4950 | 9070<br>HL-4R | 50:50 | 50:50 | |
| | 82-96 | 58 | Port Colborne | 8000 | 14844<br>HL-8R | 40:60 | 50:50 | BL.<br>ST., SA. |
| | 83-21 | 2 | Brighton | 3400 | 27224<br>HL-4R | 40:60 | 40:60 | BL.<br>ST., SA. |
| | 83-43 | QEW | Niagara Falls | 14000 | 32481<br>HL-8R<br>HL-1R | 40:60<br>25:75 | 50:50<br>25:75 | SLG.<br>BL.<br>ST., SA. |
| | 83-48 | 7A | Port Perry | 5150 | 21372<br>HL-4R | 40:60 | 40:60 | BL.<br>ST., SA. |
| | 83-49 | 30 | Hilton | 1900 | 14024<br>HL-4R | 40:60 | 50:50 | BL.<br>ST., SA. |
| 1984 | 83-11 | QEW | Burlington | 52000 | 31794<br>HL-8R | 40:60 | 40:60 | BL.<br>ST., SA. |
| | 83-67 | 35 | Newcastle | 10000 | 22332<br>HL-4R | 30:70 | 30:70<br>25:75 | BL.<br>ST., SA. |
| | 83-68 | 401<br>403 | Mississauga | 124200 | 29176<br>HL-8R | 40:60 | 40:60 | BL.<br>ST., SA. |
| | 83-70 | 55 | Niagara | 4950 | 35259<br>HL-8R | 50:50 | 50:50 | BL.<br>ST., SA. |
| | 84-11 | QEW | Mississauga | 120000 | 22886<br>HL-4R | 40:60 | 40:60 | BL.<br>ST., SA. |
| | 84:35 | 3 | Niagara | 4400 | 47372<br>HL-8R | 40:60 | 40:60<br>20:80 | SLgg. |
| | 83-27 | 427 | Toronto | 20300 | 36441<br>HL-8R | 50:50 | 50:50 | BL.<br>ST., SA. |
| | 83-71 | 401 | Toronto | 158600 | 124167<br>HL-8R | 50:50 | 50:50 | BL.<br>ST., SA. |

REGION: EASTERN

| YEAR | CONTRACT | HWY | LOCATION | A.A.D.T. | QUANTITY | CONT. DESIGN RATIO | Mix DESIGN RATIO | VIRGIN AGG.' Used |
|---|---|---|---|---|---|---|---|---|
| 1982 | 82-27 | 648 | HighlandGrove | 350 | 10402 HL-4R | 40:60 | 40:60 | BL. ST., SA. |
| | 82-60 | 62 | Barry Bay | 1800 | 41257 HL-4R | | 60:40 70:30 | BL. ST., SA. |
| 1984 | 84-12 | 30 | Codrington | 1900 | 12205 HL-4R | 40:60 | 40:60 | BL. ST., SA. |
| | 84-14 | 2 | Trenton | 12000 | 6661 HL-1R | 50:50 | 30:70 | BL. ST., SA. |

REGION: NORTHERN

| YEAR | CONTRACT | HWY | LOCATION | A.A.D.T. | QUANTITY | CONT. DESIGN RATIO | Mix DESIGN RATIO | VIRGIN AGG. Used |
|---|---|---|---|---|---|---|---|---|
| 1983 | 83-226 | 63 | Red Bridge | 1250 | 46765 HL-4R | 60:40 | 60:40 | SCR., ST., SA., |
| 1984 | 83-04 | 11 | Severn Bridge | 12400 | 21950 HL-4R | 70:30 | 70:30 40:60 | 16mm A. |
| | 83-201 | 17 94 | North Bay | 5000 | 34026 HL-4R | 60:40 | 70:30 60:40 | 16mm A. |
| | 83-212 | 11 558 | Haileybury | 32000 | 46765 HL-4R | 60:40 | 25:75 | SCR., ST., SA., |
| | 83-214 | 11 | North Bay | 2800 | 48600 HL-4R | 70:30 | 70:30 60:40 | SCR., ST., SA., |
| | 83-222 | 69 | Sudbury | 3900 | 58872 HL-4R | 70:30 | 70:30 | |

REGION: NORTHWESTERN

| YEAR | CONTRACT | HWY | LOCATION | A.A.D.T. | QUANTITY | CONT. DESIGN RATIO | Mix DESIGN RATIO | VIRGIN AGG. Used |
|---|---|---|---|---|---|---|---|---|
| 1982 | 82-201 | 11<br>584 | Longlac | 900 | 48754<br>HL-4R | | 70:30<br>60:40<br>50:50 | SA.<br>GR.SCR./ |
| | 82-202 | 102<br>11 | Sistoren's Corner | 1600 | 38765<br>HL-4R | 40:60 | 50:50 | HL-4 BL.<br>ST. / SA. |
| 1983 | 82-207 | 11<br>17 | Thunder Bay | 10000 | 21933<br>HL-4R | 40:60 | 50:50 | HL-4 BL.<br>ST. / BL. |
| | 82-212 | 556 | Sault Ste. Marie | 1200 | 5908<br>HL-4R | 40:60 | 50:50 | HL-4 BL.<br>ST. / SA. |
| | 82-218 | 101 | Chapleau | 600 | 43613<br>HL-4R | 65:35 | 65:35 | HL-4 BL.<br>ST. / SA. |
| | 82-226 | 11 | Burchell Lake | 550 | 16594<br>HL-4R | 70:30 | 40:60 | HL-4 BL.<br>ST. / SA. |
| | 83-203 | 11<br>17 | Thunder Bay | 4150 | 66956<br>H1-4R | 50:50<br>30:70 | 50:50<br>30:70 | HL-4 BL.<br>ST. / SA. |
| | 83-204 | 584 | Geraldton | 600 | 40825<br>HL-4R | 17:83 | 17:83 | HL-4 BL.<br>ST. / SA. |
| 1984 | 83-225 | 11<br>582 | Red Rock | 2800 | 58583<br>HL-4R | 60:40<br>35:65 | 60:40<br>35:65 | HL-4 BL.<br>ST./ /SA.<br>SCR. |
| | 83-231 | 590 | Nolalu | 600 | 9596<br>HL-4R | 30:70 | 30:70 | HL-4 BL.<br>ST. / SA.<br>/GR. SCR. |
| | 84-201 | 17 | Iron Bridge | 3100 | 55591<br>HL-4R | 40:60<br>25:75 | 40:60<br>25:75 | HL-4 BL.<br>ST. / SA.<br>/GR. SCR. |
| | 84-209 | 11<br>502 | Mine Center | 650 | 54833<br>HL-4R | 30:70 | 30:70 | HL-4 BL.<br>ST. / SA. |

# APPENDIX 2

## MIX DESIGN INFORMATION

| CONTRACT | LIFT | MIX DESIGN | | | | | DESIGN MIX VALUES | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | RAP | C.A. | $F.A._1$ | $F.A._2$ | A.C. | A.C. | S.A. | VOIDS | FLOW | STAB. | V.M.A. (Specs. |
| 82-13 | B | 40 | 20 | 40 | - | 3.6 | 5.2 | 62.9 | 3.0 | 10.3 | 11875 | 15.5 (15 |
| | B | 50 | 15 | 35 | - | 3.2 | 5.2 | 64.2 | 2.7 | 11.0 | 11876 | 15.0 (15.5) |
| | B | 45 | 18 | 37 | - | | | | | | | |
| 82-30 | B | 70 | 20 | 10 | - | 1.4 | 5.6 | 61 | 2.4 | 14.9 | 14100 | 12.8 (15 ) |
| | S | 60 | 20 | 10 | 10 | 2.9 | 6.4 | 64 | 3.0 | 15.2 | 10500 | 15 (15.5) |
| | S | 60 | 20 | 20 | - | 2.5 | 6.0 | 64 | 3.0 | 13.0 | 13200 | 14.2 (15.5) |
| | S | 50 | 20 | 30 | - | 2.8 | 5.3 | 66 | 3.6 | 13.2 | 13500 | 14.5 (15.5) |
| 82-93 | S | 70 | 20 | 10 | - | 1.1 | 5.3 | 55 | 2.9 | 13.8 | 13879 | 13.8 (14.5) |
| | S | 70 | 15 | 15 | - | 1.1 | 5.3 | 60 | 2.9 | 14.0 | 17600 | 14.0 (15.0) |
| 83-07 | S | 50 | 20 | 30 | - | 2.6 | 5.1 | 61 | 3.0 | 9.0 | 7800 | 14.0 (15.0) |
| 83-18 | B, S | 50 | 20 | 30 | - | 2.8 | 5.6 | 65 | 3.0 | 11.2 | 7800 | 14.5 (15.5) |
| 83-25 | B | 40 | 30 | 30 | - | 3.3 | 5.2 | 54 | 3.0 | 12.2 | 12500 | 14.8 (15.0) |
| | S | 40 | 30 | 30 | - | 3.3 | 5.2 | 54 | 3.0 | 12.2 | 12500 | 14.8 (15.0) |
| 83-60 | B | 45 | 25 | 18 | 12 | 3.0 | 5.3 | 60.5 | 3.0 | 11.3 | 12600 | 14.9 (15.0) |
| | B | 45 | 25 | 18 | 12 | 3.5 | 5.5 | 61 | 2.9 | 12.6 | 12000 | 14.7 (15.0) |
| 84-05 | B | 50 | 25 | 25 | - | 2.2 | 4.9 | 56 | 3 | 9.8 | 13000 | 12.5 (14.5) |

| CONTRACT | LIFT | MIX DESIGN | | | | | DESIGN MIX VALUES | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | RAP | C.A. | F.A.$_1$ | F.A.$_2$ | A.C. | A.C. | S.A. | VOIDS | FLOW | STAB. | V.M.A. (Specs. |
| 84-05 | S | 50 | 20 | 30 | - | 2.9 | 5.6 | 61 | 3.5 | 11.8 | 10800 | 14.5 (15.0) |
| | S | 50 | 20 | 30 | - | 3.2 | 5.2 | 61 | 3.5 | 10.1 | 8300 | 14.0 (15.0) |
| 89-06 | S | 50 | 23 | 25 | - | 3.1 | 6.1 | 62 | 3.1 | 12.2 | 12250 | 15.6 (15.0) |
| | B | 60 | 20 | 20 | - | 2.5 | 6.1 | 64.2 | 2.5 | 12.8 | 14500 | 15.2 (15.5) |
| 84-07 | B | 40 | 25 | 35 | - | 3.8 | 5.8 | 65 | 3.5 | 10.7 | 8250 | 16.3 (15.5) |
| | B | 50 | 25 | 25 | - | 2.5 | 5.2 | 62 | 3.5 | 10.8 | 10700 | 14.7 (15.0) |
| 84-29 | B, S | 50 | 20 | 30 | - | 2.8 | 5.6 | 62 | 3.7 | 11.2 | 12900 | 14.6 (15.0) |
| 84-48 | B | 50 | 20 | 30 | - | 3.3 | 5.8 | 65 | 3.7 | 11.4 | 9500 | 16.1 (15.5) |
| 84-51 | B | 50 | 25 | 25 | - | 2.3 | 5.2 | 65 | 3.3 | 10.5 | 12300 | 14.6 (15.0) |
| | S | 25 | 40 | 17.5 | 17.5 | 3.8 | 5.2 | 55 | 3.5 | 10.4 | 13300 | 15.6 (13.0) |
| 84-74 | S | 50 | 25 | 25 | - | 2.5 | 5.5 | 61 | 3.6 | 11.0 | 12700 | 14.2 (15.0) |
| | S | 40 | 30 | 30 | - | 3.0 | 5.5 | 60 | 3.6 | 11.0 | 12700 | 14.2 (15.0) |
| | S | 35 | 32 | 33 | - | 3.3 | 5.5 | 59 | 3.6 | 11.0 | 12700 | 14.2 (13.0) |
| 84-76 | B, S | 45 | 30 | 25 | - | 3.5 | 5.7 | 60 | 3.7 | 9.8 | 9100 | 15.1 (15.5) |
| | B, S | 45 | 30 | 19 | 6 | 2.8 | 5.2 | 60 | 3.3 | 10.1 | 10005 | 14.4 (15.5) |
| | | | | | | | | | | | | |

| CONTRACT | LIFT | MIX DESIGN | | | | | DESIGN MIX VALUES | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | RAP | C.A. | $F.A._1$ | $F.A._2$ | A.C. | A.C. | S.A. | VOIDS | FLOW | STAB. | V.M.A. (Specs. |
| 82-201 | B | 70 | 14 | 10 | 6 | 1.6 | 5.2 | 60 | 3 | 12.8 | 10700 | 14.7 |
| | S | 60 | 20 | 12 | 8 | 2.3 | 5.1 | 60 | 2.6 | 12.7 | 12700 | 14.7 |
| | S | 50 | 25 | 21 | 4 | 2.6 | 5.2 | 60 | 3.2 | 9.5 | 8300 | 15.0 |
| 82-202 | B | 50 | 29 | 14 | 7 | 2.5 | 5.1 | 60 | 2.6 | 11.3 | 13300 | 13.5 |
| | S | 50 | 29 | 14 | 7 | 2.5 | 5.1 | 60 | 2.6 | 11.3 | 13300 | 13.5 |
| 82-207 | B | 50 | 20 | 20 | - | 3.1 | 5.3 | 60 | 2.6 | 10.2 | 12100 | 14.1 |
| 82-212 | S | 50 | 30 | 20 | - | 3.3 | 5.3 | 60 | 3.0 | 10.0 | 12800 | 15.2 (15.0) |
| | S | 50 | 34 | 16 | - | 3.3 | 5.3 | 65 | 3.7 | 11.3 | 14184 | 16.0 |
| 82-218 | B | 65 | 19 | 11 | 5.3 | 2.8 | 5.3 | 55 | 3.0 | 10.3 | 10800 | 14.4 (14.5) |
| | B, S | 65 | 19 | 26 | - | 2.7 | 5.2 | 55 | 2.7 | 9.5 | 11500 | 14.7 (14.5) |
| | S | 65 | 14.5 | 20.5 | - | 2.4 | 5.5 | 60 | 3.7 | 10.4 | 11700 | 15.4 (15.0) |
| 82-226 | S | 40 | 22 | 38 | - | 3.6 | 5.5 | 60 | 3.4 | 9.5 | 10800 | 14.9 (15.0) |
| 83-203 | B | 50 | 22 | 21 | 7 | | 5.4 | 60 | 3.6 | 11.0 | 13700 | 15.6 (15.0) |
| | B | 50 | 27 | 23 | - | 2.8 | 5.4 | 58 | 3.7 | 10.9 | 14500 | 15.5 (15.0) |
| | S | 30 | 35 | 23 | 12 | 4.0 | 5.3 | 55 | 3.5 | 11.7 | 15000 | 14.9 (14.5) |
| 83-204 | B, S | 17 | 31 | 31 | 16, 5 | 4.6 | 5.4 | 60 | 3.8 | 8.0 | 7200 | 15.6 (15.0) |

| CONTRACT | LIFT | MIX DESIGN | | | | | DESIGN MIX VALUES | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | RAP | C.A. | $F.A._1$ | $F.A._2$ | A.C. | A.C. | S.A. | VOIDS | FLOW | STAB. | V.M.A. (Specs.) |
| 83-204 | S | 17 | 31 | 26 | 16,10 | 4.4 | 5.2 | 60 | 2.9 | 10.0 | 13000 | 14.2 (15.0) |
| 83-225 | B | 60 | 15 | 25 | - | 3.0 | 5.3 | 61.5 | 3.8 | 10.6 | 17000 | 15.6 (15.0) |
| | S | 35 | 29 | 25 | 11 | 4.1 | 5.5 | 60.0 | 3.7 | 10.9 | 14190 | 15.8 (15.0) |
| 83-231 | S | 30 | 32 | 25 | 13 | 4.4 | 5.5 | 55 | 3.3 | 8.9 | 7975 | 15.3 (14.3) |
| 84-201 | B | 40 | 21 | 29 | 10 | 4 | 5.5 | 60 | 3.8 | 9.5 | 7785 | 15.5 (15.5) |
| | S | 25 | 34 | 27 | 14 | 4.3 | 5.2 | 55 | 4.0 | 8.4 | 8300 | 15.0 (15.0) |
| 84-209 | B | 30 | 31 | 26 | 13 | 3.5 | 5.3 | 58 | 2.8 | 8.4 | 7300 | 15.0 (15.0) |
| | S | 30 | 31 | 26 | 13 | 3.5 | 5.3 | 58 | 2.8 | 8.4 | 7300 | 15.0 (15.0) |
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| CONTRACT | LIFT | MIX DESIGN | | | | | DESIGN MIX VALUES | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | RAP | C.A. | $F.A._1$ | $F.A._2$ | A.C. | A.C. | S.A. | VOIDS | FLOW | STAB. | V.M.A. (Specs.) |
| 83-226 | B | 60 | 20 | 20 | - | 2.2 | 5.5 | 59.4 | 3.2 | 10.6 | 10100 | 14.9 (15.0) |
| | S | 60 | 20 | 20 | - | 2.2 | 5.5 | 59.4 | 3.2 | 10.6 | 10100 | 14.9 (15.0) |
| 83-04 | B | 70 | 17 | 13 | - | 1.6 | 5.3 | 59.7 | 3.0 | 11.4 | 9475 | 15.3 (13.0) |
| | | 40 | 30 | 30 | - | 3.1 | 5.2 | 56.8 | 3.0 | 11.6 | 10675 | 14.8 (14.5) |
| 83-201 | B | 70 | 30 | - | - | 2.0 | 5.9 | 51.3 | 2.6 | 12.2 | 11773 | 13.3 (14.0) |
| | S | 60 | 40 | - | - | 2.3 | 4.8 | 49.7 | 2.9 | 11.5 | 12000 | 13.1 (14.0) |
| 83-212 | B | 25 | 35 | 25 | 15 | 4.7 | 5.2 | 55.4 | 3.2 | 12.1 | 11400 | 14.9 (14.3) |
| 83-214 | B | 70 | 30 | - | - | 1.3 | 4.8 | 52.9 | 2.9 | 10.7 | 11358 | 13.7 (14.5) |
| | B | 70 | 30 | - | - | 2.0 | 5.2 | 59.9 | 3.0 | 11.7 | 13949 | 13.6 (15.0) |
| | S | 60 | 23 | 7 | - | 2.2 | 5.0 | 55.3 | 3.6 | 11.3 | 11975 | 13.2 (14.5) |
| 83-222 | B | 70 | 17.5 | 12.5 | - | | 5.6 | 57.8 | 2.0 | 15.8 | 14600 | 14.4 (15.0) |
| | B, S | 70 | 30 | - | - | | 5.4 | 57.8 | 2.0 | 15.8 | 14600 | 14.4 (15.0) |
| | B | 70 | 20 | 10 | - | | 5.1 | 57.8 | 2.0 | 15.8 | 14600 | 14.4 (15.0) |
| | B, S | 70 | 20 | 10 | - | | 5.2 | 57.8 | 2.0 | 15.8 | 14600 | 14.4 (15.0) |
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EASTERN



| CONTRACT | LIFT | MIX DESIGN | | | | | DESIGN MIX VALUES | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | RAP | C.A. | $F.A._1$ | $F.A._2$ | A.C. | A.C. | S.A. | VOIDS | FLOW | STAB. | V.M.A. (Specs.) |
| 82-27 | S | 40 | 20 | 40 | - | 3.9 | 5.6 | 60 | 3.0 | 8.0 | 6750 | 13.1 (15.0) |
| 82-60 | B | 60 | 20 | 20 | - | 3.0 | 5.4 | 50 | 3.1 | 8.9 | 9800 | 14.5 (14.0) |
| | B | 70 | 15 | 15 | - | 2.6 | 5.4 | 60 | 3.0 | 10.7 | 13150 | 14.5 (15.0) |
| | S | 70 | 15 | 15 | - | 3.5 | 5.5 | 50 | 3.1 | 8.9 | 9700 | 14.9 (14.0) |
| | S | 60 | 20 | 20 | - | 3.2 | 5.6 | 60 | 3.3 | 8.8 | 10700 | 15.0 (15.0) |
| | S | 60 | 20 | 20 | - | 3.3 | 5.6 | 60 | 3.2 | 8.8 | 10700 | 15.0 (15.0) |
| 84-12 | B | 40 | 24 | 36 | - | 4.0 | 5.7 | 61.4 | 3.0 | 9.6 | 9900 | 14.9 (15.0) |
| | S | 40 | 24 | 36 | - | 3.8 | 5.6 | 61.4 | 3.5 | 9.4 | 10000 | 14.9 (15.0) |
| 84-14 | B | 30 | 35 | 35 | - | 3.9 | 5.3 | 55.7 | 3.2 | 9.2 | 11400 | 14.9 (15.0) |
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| CONTRACT | LIFT | MIX DESIGN | | | | | DESIGN MIX VALUES | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | RAP | C.A. | F.A.1 | F.A.2 | A.C. | A.C. | S.A. | VOIDS | FLOW | STAB. | V.M.A. (Specs.) |
| 82-72 | B | 40 | | | | 3.4 | 5.1 | 55 | 2.2 | 13.5 | 14300 | 13.2 (14.5) |
| 82-34 | B | 40 | | | | 3.7 | 5.8 | | | | | |
| | B | 40 | | | | 2.9 | 5.3 | | | | | |
| 82-85 | B | 40 | | | | 3.5 | 5.3 | 55 | 2.5 | 13.8 | 19100 | 14.3 (14.5) |
| 82-88 | B | 50 | | | | 2.9 | 5.8 | 60 | 2.5 | 13.7 | 19200 | 14.3 (14.5) |
| 82-96 | B, S | 50 | | | | 2.5 | 5.2 | 50 | 2.0 | 13.0 | 20000 | 14.3 (13.5) |
| 83-21 | S | 40 | 27 | 33 | - | .5 | 5.3 | 55 | 2.8 | 10.1 | 12300 | 15.0 (14.5) |
| 83-43 | B | 50 | 23 | 27 | - | 2.3 | 5.2 | 55 | 1.3 | 16.8 | 19400 | 12.1 (14.0) |
| | S | 25 | 34 | 41 | - | 3.8 | 5.3 | 55 | | | | |
| 83-48 | B, S | 40 | 27 | 27 | 6 | 2.6 | 5.1 | 55 | 2.8 | 10.6 | 12300 | 15.1 (14.5) |
| 83-49 | B | 60 | 20 | 20 | - | 2.7 | 5.6 | 57.5 | 2.5 | 12.7 | 17000 | 14. (14.5) |
| | S | 50 | 25 | 25 | - | 3.2 | 5.4 | 57.5 | 3.1 | 9.8 | 11500 | 15.5 (14.5) |
| 83-11 | B | 50 | 23 | 27 | - | 3.1 | 5.5 | 55 | 2.2 | 13.2 | 14400 | 16.3 (14.0) |
| 83-67 | B | 30 | 35 | 35 | - | 3.5 | 5.1 | 55 | | | | |
| | B | 25 | 32 | 43 | - | 4.1 | 5.2 | 60 | | | | |
| | B | 30 | 34 | 36 | - | 3.6 | 5.0 | 55 | | | | |

CENTRAL



| CONTRACT | LIFT | MIX DESIGN | | | | | DESIGN MIX VALUES | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | RAP | C.A. | $F.A._1$ | $F.A._2$ | A.C. | A.C. | S.A. | VOIDS | FLOW | STAB. | V.M.A. (Specs.) |
| 83-68 | B, S | 40 | 27 | 33 | - | 3.3 | 5.0 | 55 | 1.7 | 11.2 | 13800 | 15.3 (14.0) |
| 83-70 | B | 50 | 23 | 27 | - | 2.9 | 5.3 | 55 | 2.0 | 11.3 | 20400 | 14.4 (14.0) |
| 84-11 | | 40 | | | | 3.2 | 5.3 | | | | | |
| 84-35 | B | 40 | | | | 3.3 | 5.5 | | | | | |
| | S | 20 | 30 | 30 | | 4.4 | 5.5 | | | | | |
| 83-27 | B | 50 | 25 | 25 | - | 3.0 | 5.3 | 55 | 2.3 | 11.7 | 17300 | 13.8 |
| 83-71 | B | 50 | 25 | 25 | - | 3.0 | 5.3 | 55 | 2.3 | 11.7 | 17500 | 13.8 |
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# APPENDIX 3

## PLANT CHECK RESULTS

CENTRAL REGION

## SUMMARY OF PLANT CHECKS

| | | | A.C. | S.A. | VOIDS | FLOW | STAB. | V.M.A. | % Pass 75 um Sand | B.R.D. | M.R.D. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 82-72 | | | | | | | | | | | |
| 40:60 | n= 29 | $\bar{x}$ | 5.0 | 57.2 | 3.3 | 11.0 | 11874 | 14.2 | 4.1 | 2.412 | 2.508 |
| Bind. | | σ | .3 | 3.6 | 1.2 | 1.9 | 3008 | 1.2 | .4 | .027 | .010 |
| 82-34 | | | | | | | | | | | |
| 40:60 | | $\bar{x}$ | 6.2 | 56.9 | .9 | 17.0 | 11476 | 17.4 | 5.1 | 2.448 | 2.508 |
| Bind. | | σ | .6 | 3.9 | .9 | 1.4 | 1740 | .9 | .2 | .010 | .031 |
| 40:16 | | $\bar{x}$ | 5.1 | 54.8 | 2.2 | 14.8 | 15213 | 14.9 | 5.3 | 2.451 | 2.547 |
| Bind. | | σ | .3 | 2.4 | .7 | .5 | 3463 | 2.5 | .2 | .013 | .020 |
| 82-85 | | | | | | | | | | | |
| 40:60 | n= 43 | $\bar{x}$ | 5.4 | 53.7 | 1.2 | 15.9 | 18044 | 11.9 | 5.2 | 2.480 | 2.553 |
| Bind. | | σ | .3 | 3.1 | .9 | 2.6 | 3172 | 1.2 | .5 | .022 | .025 |
| 82-88 | | | | | | | | | | | |
| 50:50 | n= 15 | $\bar{x}$ | 5.7 | 56.8 | 1.2 | 14.3 | 18577 | 13.8 | 5.57 | 2.402 | 2.490 |
| Bind. | | σ | .3 | 2.7 | 1.0 | 2.0 | 1572 | 1.5 | .9 | .026 | .013 |
| 82-96 | | | | | | | | | | | |
| 50:50 | n= 14 | $\bar{x}$ | 5.4 | 50.3 | .3 | 20.1 | 16422 | 13.8 | 5.1 | 2.461 | 2.499 |
| Bind. & Surf. | | σ | .3 | 4.1 | .6 | 3.8 | 1912 | 1.4 | .5 | .021 | .015 |
| 83-21 | | | | | | | | | | | |
| 40:60 | n= 25 | $\bar{x}$ | 5.4 | 57.8 | 2.9 | 12.2 | 10709 | 15.3 | 3.6 | 2.407 | 2.502 |
| Surf. | | σ | .3 | 5.1 | 1.5 | 2.8 | 3506 | 1.8 | .4 | .043 | .012 |
| 83-43 | | | | | | | | | | | |
| 50:50 | n= 19 | $\bar{x}$ | 5.3 | 49.0 | 2.9 | 15.3 | 18126 | | 5.2 | 2.494 | 2.569 |
| Bind. | | σ | .3 | 3.4 | 1.0 | 2.3 | 3729 | | .7 | .026 | .022 |
| 25:75 | n= 20 | $\bar{x}$ | 5.1 | 52.5 | 2.6 | 17.4 | 24042 | 9.5 | 4.7 | 2.831 | 2.908 |
| Surf. | | σ | .2 | 2.6 | .5 | 2.2 | 2757 | 1.3 | .8 | .039 | .044 |
| 83-48 | | | | | | | | | | | |
| 40:60 | n= 45 | $\bar{x}$ | 5.1 | 53.2 | 1.6 | 12.3 | 12145 | 13.7 | 4.6 | 2.429 | 2.499 |
| Bind. & Surf. | | σ | .3 | 3.1 | .7 | 1.8 | 1736 | .5 | .6 | .021 | .014 |
| 83-49 | | | | | | | | | | | |
| 60:40 | n= 9 | | 5.5 | 61.3 | 2.2 | 12.8 | 12721 | 13.7 | 4.7 | 2.432 | 2.495 |
| Bind. | | | .2 | 1.0 | .8 | 1.3 | 2922 | .5 | .4 | .030 | .009 |
| 50:50 | n= 10 | $\bar{x}$ | 5.4 | 58.2 | 2.4 | 12.5 | 12655 | 13.6 | 4.1 | 2.420 | 2.496 |
| Surf. | | σ | .3 | 3.2 | .7 | 3.3 | 2067 | .5 | .4 | .013 | .006 |

CENTRAL REGION

## SUMMARY OF PLANT CHECKS

| | | | A.C. | S.A. | VOIDS | FLOW | STAB. | V.M.A. | % Pass 75 um Sand | B.R.D. | M.R.D. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 83-11 | | | | | | | | | | | |
| 50:50 | n= 18 | $\bar{x}$ | 5.5 | 54.6 | 2.0 | 16.8 | 14346 | 15.9 | 5.4 | 2.476 | 2.545 |
| Bind. | | σ | .3 | 4.2 | 1.0 | 2.4 | 2723 | .7 | .6 | .017 | .015 |
| 83-67 | | | | | | | | | | | |
| 30:70 | n= 6 | $\bar{x}$ | 5.1 | 54.2 | 1.3 | 12.0 | 12815 | 13.1 | 3.6 | 2.456 | 2.510 |
| Bind. | | σ | .3 | 2.9 | .4 | 1.6 | 1319 | .3 | .6 | .010 | .004 |
| 25:75 | n= 19 | $\bar{x}$ | 5.2 | 59.4 | 1.6 | 12.0 | 13000 | 13.7 | 3.2 | 2.441 | 2.499 |
| Bind. | | σ | .2 | 2.5 | .6 | 1.9 | 2127 | .4 | .5 | .016 | .005 |
| 30:70 | n= 34 | $\bar{x}$ | 5.1 | 55.8 | 1.7 | 11.7 | 12775 | 13.5 | 3.6 | 2.440 | 2.505 |
| Bind. | | σ | .3 | 2.7 | .8 | 2.4 | 1924 | .8 | .6 | .018 | .022 |
| 83-68 | | | | | | | | | | | |
| 40:60 | n= 60 | $\bar{x}$ | 4.9 | 57.2 | 1.8 | 11.7 | 17137 | 13.5 | 4.2 | 2.439 | 2.517 |
| Bind. & Surf. | | σ | .3 | 3.5 | .7 | .9 | 1443 | .8 | .7 | .013 | .015 |
| 83-70 | | | | | | | | | | | |
| 50:50 | n= 56 | $\bar{x}$ | 5.5 | 51.9 | .8 | 22.0 | 15075 | 12.0 | .9 | 2.460 | 2.511 |
| Bind. | | σ | .4 | 3.5 | .9 | 5.0 | 2893 | 1.1 | 1.0 | .028 | .019 |
| 83-11 | | | | | | | | | | | |
| 40:60 | n= 24 | $\bar{x}$ | 5.6 | 55.4 | 1.4 | 16.1 | 14829 | 13.9 | 5.3 | 2.517 | 2.550 |
| Bind. | | σ | .3 | 3.8 | .8 | 3.1 | 3176 | 1.0 | .6 | .102 | .017 |
| 84-35 | | | | | | | | | | | |
| 40:60 | | | | | | | | | | | |
| Bind. | | | | | | | | | | | |
| 20:80 | n= 25 | $\bar{x}$ | 5.8 | 53.8 | 3.9 | 23.6 | 18903 | 9.4 | 3.9 | 2.777 | 2.910 |
| Surf. | | σ | .3 | 2.1 | .4 | 2.6 | 1731 | 1.2 | .4 | .314 | .038 |
| 83-27 | | | | | | | | | | | |
| 50:50 | n= 40 | $\bar{x}$ | 5.2 | 47.4 | 4.9 | 1.7 | 17577 | 13.6 | 13.0 | 2.455 | 2.555 |
| Bind. | | σ | .3 | 4.0 | .4 | .9 | 2388 | 1.7 | 1.2 | .019 | .019 |
| 83-71 | | | | | | | | | | | |
| 50:50 | n= 83 | $\bar{x}$ | 5.2 | 46.8 | 5.2 | 2.0 | 17886 | 13.3 | 13.4 | 2.452 | 2.556 |
| Bind. | | σ | .3 | 3.6 | .5 | 1.0 | 2265 | 1.1 | .6 | .017 | .022 |

EASTERN REGION

## SUMMARY OF PLANT CHECKS

| | | | A.C. | S.A. | VOIDS | FLOW | STAB. | V.M.A. | % Pass 75 um Sand | B.R.D. | M.R.D. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 82-27 | | | | | | | | | | | |
| 40:60 | n= 13 | $\bar{x}$ | 5.5 | 59.5 | 3.4 | 8.2 | 9831 | 15.1 | 3.7 | 2.414 | 2.500 |
| Surf. | | σ | .3 | 3.3 | .9 | 1.0 | 1345 | .5 | .5 | .015 | .012 |
| 82-60 | | | | | | | | | | | |
| 60:40 | n= 9 | $\bar{x}$ | 5.2 | 58.4 | 4.7 | 8.6 | 9281 | 15.3 | 3.8 | | |
| Blnd. | | σ | 1.0 | 3.6 | 2.7 | 1.5 | 1260 | .7 | .5 | | |
| 70:30 | n= 30 | $\bar{x}$ | 5.6 | 59.8 | 3.3 | 8.9 | 11634 | 15.1 | 4.2 | 2.406 | 2.400 |
| Blnd. | | σ | .3 | 4.6 | .8 | .9 | 1382 | 4.2 | .5 | .010 | .000 |
| 70:30 | n= 9 | $\bar{x}$ | 5.8 | 59.8 | 3.2 | 10.9 | 12732 | 15.4 | 4.2 | | |
| Surf. | | σ | .3 | 4.3 | 1.0 | 1.2 | 1351 | .8 | .4 | | |
| 60:40 | n= 41 | $\bar{x}$ | 5.8 | 58.4 | 2.9 | 8.3 | 10346 | 15.1 | 3.9 | | |
| Surf. | | σ | .3 | 5.1 | .9 | 1.0 | 1419 | .8 | .5 | | |
| 60:40 | n= 8 | $\bar{x}$ | 5.9 | 61.3 | 3.5 | 10.6 | 12731 | 15.5 | 4.3 | | |
| Surf. | | σ | .3 | 5.0 | .9 | 1.1 | 1468 | .6 | .5 | | |
| 84-12 | | | | | | | | | | | |
| 40:60 | n= 4 | $\bar{x}$ | 5.6 | 58.8 | 2.6 | 12.4 | 12111 | 13.7 | 3.8 | 2.426 | 2.490 |
| Blnd. | | σ | .3 | 3.9 | .3 | 1.1 | 1081 | .5 | .3 | .009 | .005 |
| 40:60 | n= 4 | $\bar{x}$ | 5.5 | 59.3 | 2.5 | 12.4 | 11934 | 13.7 | 4.2 | 2.443 | 2.489 |
| Surf. | | σ | .4 | 3.6 | .3 | 1.1 | 1081 | .5 | .5 | .038 | .008 |

NORTHERN REGION

## SUMMARY OF PLANT CHECKS

| | | | A.C. | S.A. | VOIDS | FLOW | STAB. | V.M.A. | % Pass 75 um Sand | B.R.D. | M.R.D. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 83-226 | | | | | | | | | | | |
| 60:40 | n= 12 | $\bar{x}$ | 5.4 | 64.5 | 3.4 | 10.2 | 11535 | 14.8 | 4.6 | | |
| Bind. | | σ | .1 | 2.3 | .7 | .5 | 1142 | .4 | .1 | | |
| 60:40 | n= 14 | $\bar{x}$ | 5.4 | 62.6 | 2.7 | 10.8 | 12015 | 14.3 | 4.7 | | |
| Surf. | | σ | .4 | 1.9 | 1.1 | .7 | 782 | .3 | .2 | | |
| 83-201 | | | | | | | | | | | |
| 70:30 | n= 8 | $\bar{x}$ | 4.9 | 50.7 | 1.8 | 13.2 | 14920 | 12.9 | 9.1 | | |
| Bind. | | σ | .2 | 2.8 | .2 | .7 | 874 | .3 | .2 | | |
| 60:40 | n= 6 | $\bar{x}$ | 4.8 | 49.4 | 2.0 | 13.0 | 15084 | 12.7 | 9.4 | | |
| Surf. | | σ | .3 | 3.4 | .3 | .7 | 1694 | .4 | .2 | | |
| 83-212 | | | | | | | | | | | |
| 25:75 | | $\bar{x}$ | 5.4 | 55.5 | 3.7 | 11.9 | 14889 | 14.8 | 3.9 | | |
| Bind. | | σ | .1 | 1.8 | .3 | .8 | 1241 | .9 | .3 | | |
| 83-214 | | | | | | | | | | | |
| 70:30 | n= 2 | $\bar{x}$ | 4.9 | 63.4 | 3.6 | 11.4 | 15509 | 13.8 | 9.0 | | |
| Bind. | | σ | .1 | 1.3 | .1 | .6 | 243 | .14 | .14 | | |
| 70:30 | n= 12 | $\bar{x}$ | 5.3 | 63.3 | 2.9 | 12.5 | 13949 | 13.9 | 8.4 | | |
| Bind. | | σ | .3 | 4.6 | .5 | .8 | 1067 | .35 | .32 | | |
| 60:40 | n= 7 | $\bar{x}$ | 5.1 | 58.1 | 3.0 | 10.9 | 13958 | 13.9 | 7.1 | | |
| Surf. | | σ | .3 | 4.5 | .3 | .7 | 580 | .5 | .3 | | |
| 83-222 | n= 4 | $\bar{x}$ | 5.8 | 65.1 | 2.1 | 12.5 | 12638 | 14.2 | 5.0 | | |
| | | σ | .4 | 2.1 | .3 | .8 | 1018 | .4 | .5 | | |
| | n= 24 | $\bar{x}$ | 5.6 | 57.8 | 1.4 | 14.0 | 12035 | 13.4 | 4.5 | | |
| | | σ | .3 | 4.5 | .3 | .1 | 1279 | .6 | .3 | | |
| | n= 10 | $\bar{x}$ | 5.2 | 55.6 | 2.0 | 13.2 | 13998 | 13.1 | 4.4 | | |
| | | σ | .2 | 2.0 | .3 | .6 | 825 | .3 | .2 | | |
| | n= 6 | $\bar{x}$ | 5.6 | 58.8 | 1.3 | 14.4 | 12528 | 13.6 | 4.4 | | |
| | | σ | .1 | .3 | .9 | .7 | | .2 | .2 | | |

NORTHWESTERN REGION

## SUMMARY OF PLANT CHECKS

| | | | A.C. | S.A. | VOIDS | FLOW | STAB. | V.M.A. | % Pass 75 um Sand | B.R.D. | M.R.D. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 82-201 | | | | | | | | | | | |
| 70:30 | n= 4 | $\bar{x}$ | 5.4 | 63.0 | 2.8 | | | 15.7 | 6.6 | | |
| Blnd. | | σ | .1 | 1.1 | .7 | | | .4 | .7 | | |
| 60:40 | n= 15 | $\bar{x}$ | 5.3 | 61.0 | 2.2 | | | 14.7 | 6.1 | | |
| Surf. | | σ | .2 | 2.8 | .4 | | | .4 | 1.0 | | |
| 50:50 | n= 8 | $\bar{x}$ | 5.4 | 61.1 | 3.9 | | | 14.0 | 8.2 | | |
| Blnd. | | σ | .2 | 2.7 | .9 | | | .9 | .6 | | |
| 82-202 | | | | | | | | | | | |
| 50:50 | n= 14 | $\bar{x}$ | 5.3 | 61.5 | 1.8 | | | 13.6 | 8.3 | | |
| Blnd. | | σ | .2 | 2.2 | .4 | | | .3 | .3 | | |
| 50:50 | n= 13 | $\bar{x}$ | 5.2 | 59.1 | 3.6 | | | 13.5 | 8.8 | | |
| Surf. | | σ | .3 | 3.5 | .7 | | | .5 | .4 | | |
| 82-207 | | | | | | | | | | | |
| 50:50 | n= 37 | $\bar{x}$ | 5.6 | 61.0 | 2.5 | 12.9 | 14793 | 14.4 | 4.7 | 2.473 | 2.542 |
| Blnd. | | σ | .4 | 4.3 | .8 | 2.2 | 1850 | 1.0 | .4 | .017 | .017 |
| 82-212 | | | | | | | | | | | |
| 50:50 | | $\bar{x}$ | 5.2 | 64.6 | 2.8 | 7.4 | 12942 | 14.9 | 3.7 | 2.471 | 2.543 |
| Surf. | | σ | .3 | 2.4 | .4 | .8 | 1635 | .4 | .3 | .010 | .010 |
| 50:50 | | $\bar{x}$ | 5.3 | 68.5 | 3.7 | 11.3 | 15554 | 16.0 | 4.9 | 2.460 | 2.550 |
| Surf. | | σ | .4 | 1.4 | 1.1 | 1.3 | 589 | .4 | .1 | .013 | .014 |
| 82-218 | | | | | | | | | | | |
| 65:35 | n= 11 | $\bar{x}$ | 5.5 | 56.9 | 2.0 | 9.4 | 12677 | 14.1 | 3.2 | 2.458 | 2.509 |
| Blnd. | | σ | .2 | 3.3 | .5 | 1.4 | 1004 | .7 | .4 | .013 | .006 |
| 65:35 | n= 27 | $\bar{x}$ | 5.4 | 57.3 | 2.9 | 10.1 | 13283 | 13.9 | 3.8 | 2.460 | 2.517 |
| Blnd&Surf. | | σ | .3 | 3.9 | .9 | 1.3 | 1000 | .7 | .4 | .022 | .016 |
| 65:35 | n= 11 | $\bar{x}$ | 5.6 | 62.2 | 3.7 | 8.6 | 13161 | 13.5 | 3.5 | 2.404 | 2.496 |
| Surf. | | σ | .1 | 1.5 | .5 | 1.1 | 1315 | .4 | .5 | .013 | .005 |
| 82-226 | | | | | | | | | | | |
| 40:60 | n= 18 | $\bar{x}$ | 5.5 | 58.9 | 3.7 | 9.7 | 11800 | 15.4 | 3.1 | 2.376 | 2.461 |
| Surf. | | σ | .1 | 4.2 | 1.0 | 1.6 | 2144 | .8 | .4 | .024 | .007 |

NORTHWESTERN REGION

## SUMMARY OF PLANT CHECKS

| | | | A.C. | S.A. | VOIDS | FLOW | STAB. | V.M.A. | % Pass 75 um Sand | B.R.D. | M.R.D. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 83-203 | | | | | | | | | | | |
| 50:50 | n= 27 | $\bar{x}$ | 5.38 | 62.4 | 4.1 | 11.4 | 12580 | 15.7 | 3.8 | 2.432 | 2.564 |
| Bind. | | o | .36 | 5.0 | 1.2 | .9 | 909 | 1.2 | .3 | .036 | .022 |
| 50:50 | n= 7 | $\bar{x}$ | 5.2 | 57.8 | 4.8 | 10.6 | 13810 | 15.9 | 3.6 | 2.414 | 2.564 |
| Bind. | | o | .1 | 1.5 | .9 | 1.6 | 1390 | .5 | .3 | .016 | .009 |
| 30:70 | n= 27 | $\bar{x}$ | 5.3 | 57.4 | 4.6 | 11.2 | 13851 | 15.9 | 3.2 | 2.445 | 2.577 |
| Surf. | | o | .3 | 4.3 | 1.0 | 1.5 | 1456 | .9 | .4 | .115 | .015 |
| 83-204 | | | | | | | | | | | |
| 17:83 | n= 12 | $\bar{x}$ | 5.7 | 61.3 | 3.3 | 8.5 | 7798 | 15.4 | 3.6 | 2.390 | 2.471 |
| Bind&Surf. | | o | .3 | 3.2 | .5 | .7 | 1039 | .5 | .2 | .010 | .008 |
| 17:83 | n= 40 | $\bar{x}$ | 5.3 | 60.1 | 2.7 | 9.2 | 11564 | 14.1 | 4.4 | 2.415 | 2.485 |
| Surf. | | o | .2 | 2.2 | .7 | 1.4 | 1230 | .6 | .6 | .015 | .011 |
| 83-225 | | | | | | | | | | | |
| 60:40 | n= 37 | $\bar{x}$ | 5.4 | 63.4 | 3.2 | | | 14.9 | 4.2 | | |
| Bind. | | o | .3 | 3.9 | .8 | | | .7 | .8 | | |
| 35:65 | n= 50 | $\bar{x}$ | 5.7 | 62.9 | 3.0 | | | 15.1 | 4.0 | | |
| Surf. | | o | .2 | 2.7 | 1.0 | | | .6 | .7 | | |
| 83-231 | | | | | | | | | | | |
| 30:60 | n= 21 | $\bar{x}$ | 5.4 | 56.9 | 3.9 | | | 15.1 | 3.3 | | |
| Surf. | | o | .2 | 1.8 | .7 | | | .7 | .4 | | |
| 84-201 | | | | | | | | | | | |
| 40:60 | n= 30 | $\bar{x}$ | 5.6 | 58.4 | 2.0 | | | 14.0 | 2.6 | | |
| Bind. | | o | .3 | 4.1 | .6 | | | .6 | .7 | | |
| 25:75 | n= 30 | $\bar{x}$ | 5.3 | 56.7 | 2.6 | | | 13.9 | 3.2 | | |
| Surf. | | o | .2 | 3.7 | .5 | | | .4 | .7 | | |
| 84-209 | | | | | | | | | | | |
| 30:70 | n= 39 | $\bar{x}$ | 5.2 | 59.9 | 2.7 | | | 14.5 | 3.8 | | |
| Bind. | | o | .2 | 5.1 | 1.2 | | | 1.0 | .6 | | |
| 30:70 | n= 26 | $\bar{x}$ | 5.2 | 60.1 | 3.4 | | | 15.1 | 3.4 | | |
| Surf. | | o | .2 | 3.5 | 1.2 | | | 1.1 | .7 | | |

SOUTHWESTERN REGION

## SUMMARY OF PLANT CHECKS

| | | | A.C. | S.A. | VOIDS | FLOW | STAB. | V.M.A. | % Pass 75 um Sand | B.R.D. | M.R.D. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 82-013 | | | | | | | | | | | |
| 40:60 | n= 5 | $\bar{x}$ | 5.4 | 64.2 | 2.2 | 10.7 | 13402 | 15.5 | 3.0 | | |
| Blnd. | | σ | .1 | 2.7 | .6 | .5 | 1156 | .5 | .7 | | |
| 50:50 | n= 3 | $\bar{x}$ | 5.2 | 65.6 | 2.2 | 12.1 | 16000 | 15.0 | 5.2 | | |
| Blnd. | | σ | .2 | 1.1 | .8 | 1.7 | 1223 | .6 | .2 | | |
| 45:55 | n= 14 | $\bar{x}$ | 5.2 | 64.9 | 2.2 | 11.5 | 162846 | 15.0 | 4.5 | | |
| Blnd. | | σ | .2 | 1.9 | .5 | 3.1 | 1339 | .6 | .6 | | |
| 82-30 | | | | | | | | | | | |
| 70:30 | n= 2 | $\bar{x}$ | 6.0 | 60.7 | 2.1 | 19.6 | 15567 | 13.2 | 10.8 | | |
| Blnd. | | σ | .3 | 1.3 | 1.0 | 3.0 | 1295 | .7 | .6 | | |
| 60:40 | n= 4 | $\bar{x}$ | 6.4 | 63.2 | 1.2 | 20.5 | 12148 | 13.9 | 8.9 | | |
| Surf. | | σ | .2 | 1.9 | .4 | 2.2 | 676 | .3 | 1.1 | | |
| 60:40 | n= 3 | $\bar{x}$ | 6.3 | 63.2 | 1.3 | 17.8 | 13729 | 13.1 | 12.1 | | |
| Surf. | | σ | .2 | 2.6 | .6 | 2.8 | 919 | .3 | 1.1 | | |
| 50:50 | n= 4 | $\bar{x}$ | 5.8 | 61.7 | 2.0 | 14.8 | 13146 | 12.7 | 10.1 | | |
| Surf. | | σ | .1 | 1.9 | .1 | .8 | 787 | .3 | .4 | | |
| 60:40 | n= 3 | $\bar{x}$ | 5.4 | 61.5 | 3.5 | 14.6 | 18869 | 13.2 | 10.6 | | |
| Surf. | | σ | .2 | 3.5 | 1.0 | .6 | 700 | .9 | .4 | | |
| 40:60 | n= 5 | $\bar{x}$ | 5.3 | 64.3 | 3.5 | 11.0 | 13818 | 13.7 | 8.8 | | |
| Surf. | | σ | .2 | 1.9 | .3 | .6 | 1835 | .4 | .6 | | |
| 82-93 | | | | | | | | | | | |
| 70:30 | n= 12 | $\bar{x}$ | 5.6 | 60.1 | 1.4 | 15.8 | 14968 | 12.8 | 10.2 | | |
| Surf. | | σ | .3 | 3.2 | .4 | 1.4 | 1280 | .6 | .6 | | |
| 70:30 | n= 10 | $\bar{x}$ | 5.5 | 62.4 | 2.9 | 13.9 | 17748 | 13.6 | 9.3 | | |
| Surf. | | σ | .4 | 4.3 | .4 | 1.2 | 2469 | .6 | .5 | | |
| 83-07 | | | | | | | | | | | |
| 50:50 | n= 8 | $\bar{x}$ | 5.6 | 62.5 | 1.5 | 11.4 | 10884 | 13.9 | 7.1 | 2.425 | 2.506 |
| Surf. | | σ | .4 | 2.2 | .9 | 2.1 | 1473 | .5 | .5 | | .010 |
| 83-18 | | | | | | | | | | | |
| 50:50 | n= 24 | $\bar{x}$ | 5.9 | 65.0 | 2.8 | 12.2 | 12062 | 14.4 | 8.1 | 2.399 | 2.488 |
| Surf.&Blnd. | | σ | .3 | 2.8 | .8 | 1.6 | 1582 | .6 | .5 | .020 | .010 |

SOUTHWESTERN REGION

## SUMMARY OF PLANT CHECKS

| | | | A.C. | S.A. | VOIDS | FLOW | STAB. | V.M.A. | % Pass 75 um Sand | B.R.D. | M.R.D. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 83-25 | | | | | | | | | | | |
| 40:60 | n= 7 | $\bar{x}$ | 5.2 | 52.9 | 2.6 | 12.7 | 11465 | 14.3 | 6.1 | 2.489 | 2.576 |
| Blnd. | | σ | .2 | 2.0 | .8 | 2.3 | 1633 | .6 | .9 | .020 | .004 |
| 40:60 | n= 5 | $\bar{x}$ | 5.3 | 53.0 | 2.8 | 12.4 | 11761 | 14.2 | 6.3 | 2.491 | 2.578 |
| Surf. | | σ | .2 | 2.3 | .6 | 2.5 | 2410 | .6 | .3 | .015 | .008 |
| 83-60 | | | | | | | | | | | |
| 45:55 | n= 10 | $\bar{x}$ | 5.0 | 60.2 | 2.6 | 9.3 | 11619 | 14.6 | 8.4 | 2.454 | 2.558 |
| Blnd. | | σ | .2 | 2.7 | 1.0 | .6 | 1388 | 1.0 | 1.0 | .026 | .006 |
| 45:55 | n= 9 | $\bar{x}$ | 5.3 | 60.6 | 2.7 | 9.4 | 12146 | 15.0 | 7.8 | 2.381 | 2.486 |
| Blnd. | | σ | .2 | 3.5 | 1.1 | 1.1 | 1897 | .8 | .5 | .021 | .008 |
| 84-05 | | | | | | | | | | | |
| 50:50 | n= 3 | $\bar{x}$ | 5.9 | 64.9 | | | | | 5.5 | | |
| Blnd. | | σ | .4 | 5.7 | | | | | .1 | | |
| 50:50 | n= 11 | $\bar{x}$ | 6.0 | 64.5 | 1.7 | 10.8 | 11415 | 13.3 | 5.3 | | |
| Surf. | | σ | .5 | 2.9 | .7 | 1.1 | 456 | .4 | .4 | | |
| 50:50 | n= 6 | $\bar{x}$ | 5.7 | 61.4 | 2.0 | 9.8 | 10061 | 13.3 | 5.1 | | |
| Surf. | | σ | .1 | 2.0 | .8 | 1.3 | 977 | .6 | .1 | | |
| 84-06 | | | | | | | | | | | |
| 40:60 | n= 15 | $\bar{x}$ | 6.1 | 65.1 | 2.7 | 10.3 | 11121 | 14.8 | 5.0 | | |
| Blnd. | | σ | .3 | 3.7 | 1.2 | 1.6 | 1779 | .9 | .5 | | |
| 50:50 | n= 3 | $\bar{x}$ | 6.0 | 59.6 | | | | | 5.2 | | |
| Blnd. | | σ | .5 | 7.1 | | | | | .6 | | |
| 84-07 | | | | | | | | | | | |
| 40:60 | n= 7 | $\bar{x}$ | 5.6 | 59.8 | 2.8 | 7.7 | 8199 | 15.2 | 3.7 | | |
| Blnd. | | σ | .2 | 2.8 | .6 | .4 | 504 | .6 | .4 | | |
| 50:50 | n= 5 | $\bar{x}$ | 5.2 | 59.9 | 2.9 | 10.4 | 14420 | 13.5 | 4.3 | | |
| Blnd. | | σ | .2 | 2.1 | 1.1 | .9 | 2176 | 1.0 | .3 | | |
| 84-29 | | | | | | | | | | | |
| 50:50 | n= 9 | $\bar{x}$ | 5.9 | 65.0 | 1.3 | 12.9 | 13761 | 12.7 | 5.8 | | |
| Surf.&Blnd. | | σ | .3 | 2.9 | .4 | 1.2 | 2152 | .5 | 1.1 | | |
| 84-48 | | | | | | | | | | | |
| 50:50 | n= 11 | $\bar{x}$ | 6.0 | 61.3 | | | | | 4.7 | | |
| Blnd. | | σ | .3 | 2.5 | | | | | 1.1 | | |

SOUTHWESTERN REGION

## SUMMARY OF PLANT CHECKS

| | | | A.C. | S.A. | VOIDS | FLOW | STAB. | V.M.A. | % Pass 75 um Sand | B.R.D. | M.R.D. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 84-51 | | | | | | | | | | | |
| 50:50 | n= 8 | $\bar{x}$ | 5.4 | 67.9 | 2.9 | 10.5 | 16638 | 14.5 | 6.9 | | |
| Blnd. | | σ | .2 | 3.2 | 1.1 | 1.1 | 2026 | .7 | 1.5 | | |
| 25:75 | n= 10 | $\bar{x}$ | 5.3 | 55.0 | 1.3 | 11.7 | 15557 | 13.2 | 4.7 | | |
| Surf. | | σ | .3 | | .5 | 1.1 | 1293 | .7 | 1.1 | | |
| 25:75 | n= 17 | $\bar{x}$ | 5.0 | 50.0 | .8 | 12.6 | 14489 | 11.1 | 4.2 | | |
| Surf. | | σ | .2 | 2.3 | .5 | 1.1 | 1682 | 1.3 | .3 | | |
| 84-74 | | | | | | | | | | | |
| 50:50 | n= 8 | $\bar{x}$ | 5.1 | 59.2 | 2.8 | 10.4 | 11829 | 13.0 | 5.4 | 2.404 | 2.484 |
| Surf. | | σ | .5 | 5.1 | 1.2 | 1.7 | 1423 | .6 | .7 | .017 | .029 |
| 40:60 | n= 3 | $\bar{x}$ | 4.7 | 56.8 | 3.8 | 10.7 | 11883 | 13.3 | 4.8 | 2.418 | 2.493 |
| Surf. | | σ | .6 | 6.2 | 2.5 | 1.5 | 945 | 1.0 | .5 | .000 | .000 |
| 35:65 | n= 4 | $\bar{x}$ | 5.0 | 56.9 | 4.2 | 8.4 | 9426 | 14.3 | 4.5 | 2.358 | 2.458 |
| Surf. | | σ | .2 | 4.9 | 1.0 | .9 | 1916 | .8 | .7 | .000 | .000 |
| 84-76 | | | | | | | | | | | |
| 45:55 | n= 34 | $\bar{x}$ | 5.1 | 59.4 | 2.8 | 9.1 | 11188 | 14.0 | 9.8 | | |
| Surf | | σ | .6 | 9.6 | .6 | 1.7 | 1405 | .3 | .6 | | |

# APPENDIX 4

## PENETRATION PREDICTION FORMULA

# memorandum

Ontario

To: Regional Managers of Construction Office
Regional Managers Engineering and Right-of-Way Office

Date: September 17, 1985.

## Predicting Asphalt Cement Penetration of RHM

Since my presentation of a formula at last years Asphalt Seminar to predict the final penetration (on the road) of RHM, I have a few enquiries from the regions regarding its use. Also, since then, I have refined the formula based on further evaluation of the data from the past three years. The correlation between the field data and the predicted values shows the formula, with a correlation coefficient of r = 0.88, can be reliably used for such purpose. Therefore, this memo is to present an update as well as to confirm what has been given over the phone to different regional staff.

The formula is shown below and it is noted that, originally, I developed the formula on the basis of known A.C. contents for the RHM, the RAP and the virgin A.C., i.e. for a given mix design. However, for predicting A.C. penetration when only the recycling ratio is known, the x, y, and z in the formula can approximate to the percentage of the RAP (x) and virgin materials (y), when z = 100.

$$\log Pp = \frac{1}{z} \left[ x \log (Cao\ Po) + y \log (Can\ Pn) \right] \quad .....(1)$$

Where: Pp = Predicted penetration of RHM.

Po = Penetration of recovered A.C. from RAP

Pn = Penetration of virgin A.C.

z = % A.C. in RHM

x = % of recovered A.C. from the RAP in a RHM

= (% RAP x % recovered A.C.)/100

y = % of virgin A.C. added to RHM

= z - x.

Cao = Aging factor of old asphalt (= 0.72)

Can = Aging factor of virgin asphalt

For 70 : 30 use 0.40
60 : 40 .. 0.49
50 : 50 .. 0.53
40 : 60 .. 0.54
30 : 70 .. 0.55

.....2/

Example: For a 70 : 30 RHM

Po = 30 PEN % A.C. in RAP = 4.0%

Pn =300 PEN

z =5.0% x = 2.8%, y = 2.2%

$$\log Pp = \frac{1}{5.0}\left[2.8 \log (0.72 \times 30) + 2.2 \log (0.4 \times 300)\right]$$

$$= 1.6622$$

$$Pn = \underline{\underline{46 \text{ pen}}}$$

This formula can also be re-arranged to the following form for <u>determining the grade of virgin A.C.</u> required for RHM:

$$\log Pn = \frac{z \log Pd - x \log (0.72\ Po)}{z - x} - \log Can \quad .....(2)$$

where :

Pn = required virgin A.C. penetration

Pd = desired penetration of RHM in pavement (e.g. 60% of the A.C. penetration of the A.C. grade normally used in a virgin mix.)

Example: Pd = 60 pen, z = 5.0%
Pn = 30 pen, x = 2.0%

For a 70 : 30 RHM, Can = 0.4

$$\log Pn = \frac{5.0 \log 60 - 2.0 \log (0.72 \times 30)}{5.0 - 2.0} - \log 0.4$$

$$= 2.472$$

$$Pn = 296$$

∴ use 300/400 Grade A.C.

However, if one wants to examine whether a certain <u>proportion of RAP</u> can be used in a RHM, when an A.C. penetration is targeted at a certain desirable level, the following formula may be used (re-arranged from (2) ).

$$\% \text{ RAP} = \frac{z\,[\log Pd - \log(\text{can } Pn)] \times 100}{x\,[\log(0.72\,Pa) - \log(\text{Can } Pn)]} \quad \ldots\ldots(3)$$

Example : Pd = 60 pen  x = 4.0 %
Po = 30 pen  z = 5.0%
Pn =300 pen

for a 70 : 30 RHM

$$\% \text{ RAP} = \frac{5.0\,[\log 60 - \log(0.4 \times 300)]}{4.0\,[\log(0.72 \times 30) - \log(0.4 \times 300)]}$$

$$= \underline{\underline{51\%}}$$

If there is any further questions regarding the above, please contact me.

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cc: R. McLuckie
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